257

THE WARNER OBSERVATORY

28270

HISTORY AND WORK

ADDENDA.

The number of nebulæ discovered at the Warner Observatory up to Jan. 1, 1887. rejecting those reserved for verification and further examination, is 540. The work of the current year will be not only a continuation of that pursued during the past three years, but also the study of such of those nebulæ found by former discoverers, as shall present themselves in the quest for new ones, which shall seem to possess sufficient attractiveness to warrant the necessary outlay of time.

Since the list of the Warner prizes was electrotyped, the following comet prizes have been paid:

DATE.	DISCOVERER.	AM'T OF PRIZE.
Sept. 26, 1886,	Finlay, Cape of Good Hope,	$100.
Oct. 4, "	Barnard,	100.
Jan. 18, 1887,	Thome, Cordoba, S. A.,	100.
Jan. 22, "	Brooks,	100.
Jan. 24, "	Barnard,	100.
	Remuneration to judges,	75.
		——$575.

One gold medal to Edward D. T. Swift, for discovery of nebulæ.

ERRATA.

Page 11, first line, for "Boss," read Prof. Lewis Boss, Albany, N. Y.

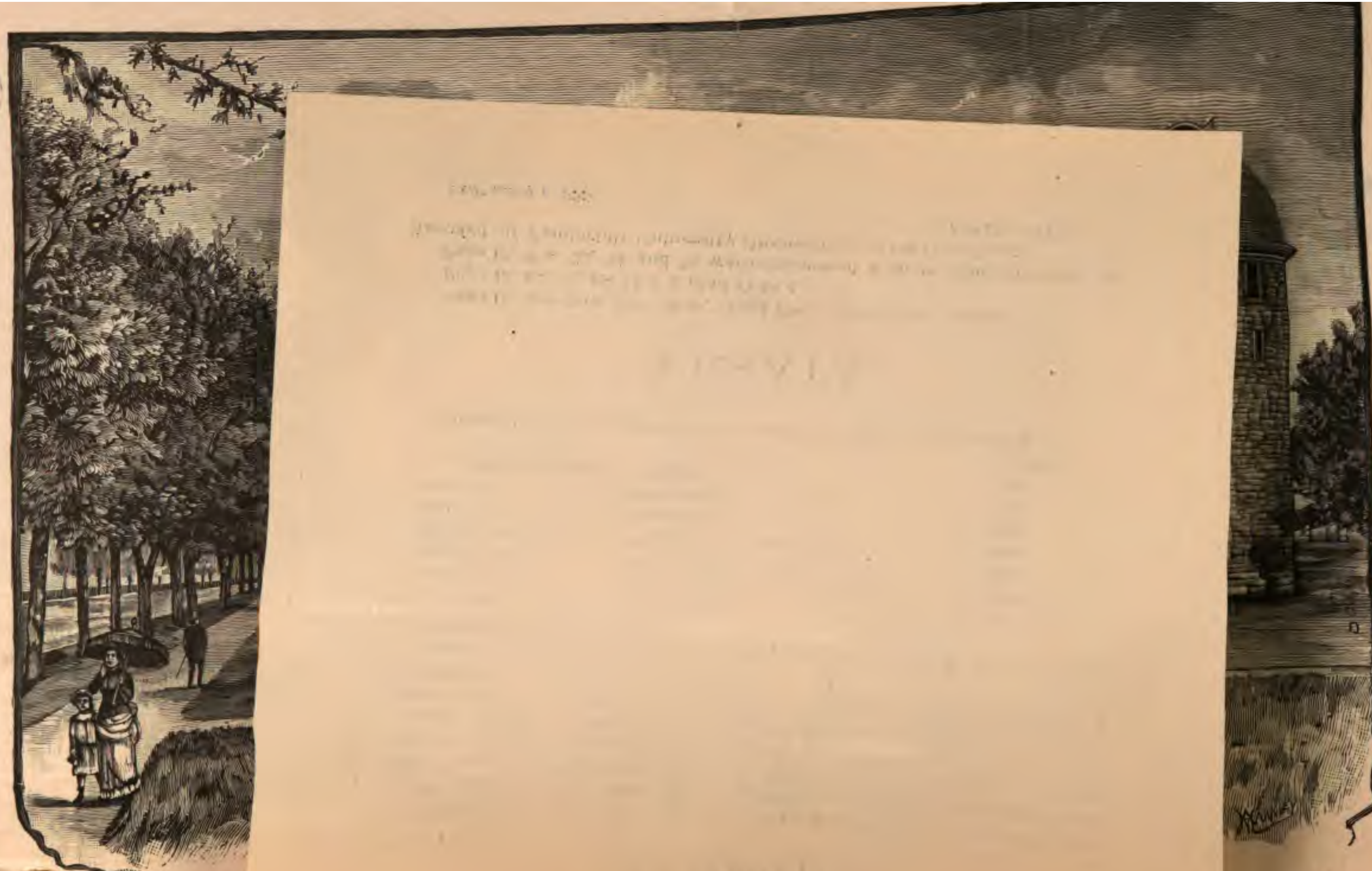
Page 13, No. 12, for 11 8 4, read 11 18 4.

Page 17, Nos. 32, 33 and 34 were discovered a short time previous by Barnard, of Vanderbilt University Observatory, Nashville, Tenn.

LEWIS SWIFT.

February 1, 1887.

ROCHESTER, N. Y.:
DEMOCRAT AND CHRONICLE BOOK AND JOB PRINT.
1887



28270

HISTORY AND WORK

—OF—

28270

The Warner Observatory,

ROCHESTER, N. Y.

1883-1886.

VOL. I.

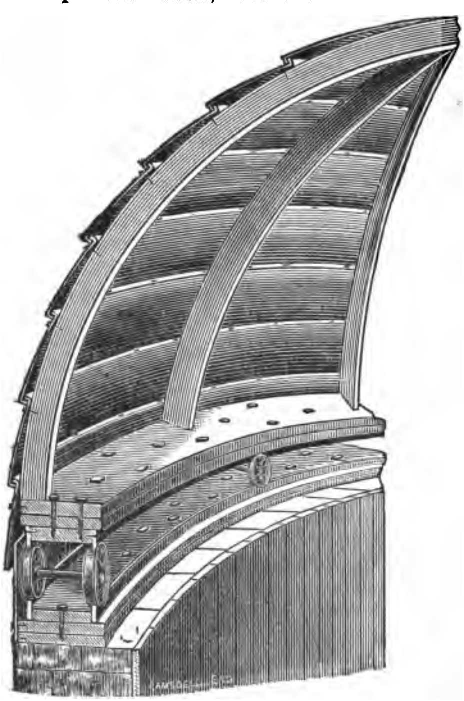
ROCHESTER, N. Y.:
DEMOCRAT AND CHRONICLE BOOK AND JOB PRINT.
1887

TABLE OF CONTENTS.

	Page.
Warner Observatory,	Frontispiece.
History, Descriptive Work,	5
The Dome, Section of	6
Comet Prizes, Awards of	10
Warner Gold Medals,	11
" " " Winners of,	11
Nebulæ, Discoveries of, at Warner Observatory,	12-22
Comet Prize Essay, (Boss),	25
Sky Glow Essay Prize Winners,	31-70

weighty as possible, under the delusive idea that if heavy they must needs be strong. Another prevalent error that has obtained is that powerful steam or gas motors are necessary to rotate them. To revolve the Warner dome, pulling or pushing—depending on the direction desired—on a perpendicular arm of tough oak, attached to the ring is all that is required, and this simple and inexpensive device is sufficient also for a dome forty feet in diameter, if properly made. I have seen this dome completely revolved by the hand of a boy of seventeen in 47 seconds, and, pulling with the middle finger of one hand, in 70 seconds. The only drawback to this ease of movement is its rotation, when the shutter is open, by the winds, which, however, is remedied by a simple device.

In constructing a dome one essential is not to be overlooked, viz: the width of the ring or sole-plate, as it is this rather than its ribs that constitutes its sinews, as no matter how strongly it may be ribbed, the ring, after the wear of a few years, is liable to become elliptical, and therefore inoperative beyond restoration. Our ring is composed of two thicknesses of 1 3-4 inch pine joined together with white lead paint (instead of glue and well bolted and spiked together. On the under side is bolted another thickness of the pine, though only as wide as the distance apart of the car-wheels, or about eight inches, which leaves on either side the upper portion projecting over the lower. Each of the upper layers are 15 inches wide. To both inner and outer edges of this narrow under-strip steel wagon tire is bolted with coach screws, the former being two, and the latter two and a quarter inches wide, and 5-16 of an inch thick. These form the upper tracks, whose edges rest on the faces of the wheels. It must be borne in mind that the steel tracks largely prevent sagging of the ring between the wheels. The wall-plate is the exact counterpart of the ring, save that the narrow strip is at the top. The wheels, which are ten inches in diameter (and should have been fifteen), are flanged like car wheels, and are attached, one on each end of a short shaft. As I feared the machinist would fail to secure the exact relative proportions in size, the wheels were left loose on the shaft and may revolve if necessary. The pairs are not tied together, as it involves a useless expense not only, but also an increase of friction. Twelve pairs were at first used, but were soon reduced to eight.



The dome is covered with galvanized iron, formed to fit the ribs, and riveted at the angles, as shown in fig. 1. The lower sheet is strongly nailed to the outer edge of the ring, and renders sagging between the wheels an impossibility. As in every direction the dome is an arch, and greatly stiffened by the angles, the ribs, except the two main ones, after the completion of the dome are of little use, save in the upper portions where they

were found convenient as a foundation upon which to nail sheathing to prevent the dripping of condensations. The condensations on the lower half, which is more nearly perpendicular, run down the iron and out between the angles. The ribs, five inches wide, are of 3-4 inch pine, twofold, with the lower ends merely nailed to the ring. The two main ribs are also of pine, thick and wide enough to project well above the outside of the dome, which prevents snow and ice from impeding the opening and closing of the shutter, which is worked by an endless chain. They are five feet apart, and the interval is covered by a single curved shutter which runs on gas pipe tracks off to one side, and may be opened to any width desired up to five feet. It is a great advantage to the observer to be able in time of hard winds to partially close the shutter.

The estimated weight of the dome is 3 tons, while the weight of the Harvard Observatory dome (same size) is 14 tons.

THE PIER.

The pier is round, 20 feet in diameter at the base, and tapering to 9 feet at the floor of the dome-room, where is placed, *beneath the floor*, a capstone 9 feet in diameter and weighing 8 tons. On this is built the rectangular pier on which the great telescope is mounted.

THE TELESCOPE.

The telescope was made by Alvan Clark & Sons, of Cambridgeport, Mass. Focal length, 22 feet; aperture of object glass, 16 inches; height of object glass from floor when pointing to zenith, 24 feet; interval between crown and flint lenses, 3.5 inches; diameter of objective of finder, 3 1-4 inches; diameter of right ascension circle, 20 inches; of declination circle, 28 inches. The right ascension circle is graduated to 1 m. of time; the declination circle to 10 sec. of arc. The tube is of steel, 14 inches in diameter at the eye end and enlarges to 18 in the middle and at the object end.

When horizontal and in the meridian, the telescope is 51 feet above the surrounding lawn, 330 feet above lake Ontario, and 564 feet above the level of the sea.

The optical center of the field of view is indicated by wires, visible without artificial illumination, crossing each other at right angles with another inclined at an angle of 45 deg., so that the difference both in right ascension and declination of a nebula from a neighboring star may, if desired, be quickly ascertained by counting the clicks of the telegraph sounder.

THE MICROMETER.

The filar position micrometer, of great excellence, was made by the Clarks. It has 4 eye-pieces with powers of from 195 to 1,250. The position circle is 6 inches in diameter. Gas instead of oil is used for the illuminant. The micrometer is not used in the nebula-work of this observatory.

COMET SEEKER.

This instrument (the telescope constantly used for nearly 30 years) is still employed in comet seeking from the flat graveled roof of the attached dwelling, which affords an admirable place for the work, though a frigid one in winter.

DRIVING CLOCK.

The driving clock is of the "Bond Spring Governor" variety, and works very well. It is started and stopped, the telescope clamped and unclamped and moved to bisection, by means of cords, without descending from the observing chair, or even removing the eye from the telescope.

THE OBSERVING CHAIR.

The chair, which is strong and inexpensive, was designed with special reference to sweeping. Its seats fold upward at the will of the observer and thus render his position quite comfortable, while its curvature enables him to retain at every elevation the same relative distance from the eye-piece. A portion of it is shown in Plate 1. It runs on two parallel circular tracks of 7-16 square iron, and, therefore, no matter in what directional position it may be, cannot come in collision with either eye or object end of the telescope. which, when the room is absolutely dark, is a very assuring consideration.

THE AUTOMATIC R. A. CIRCLE.

Upon this exceedingly useful and time-saving device where right ascensions, already reduced to any desired epoch, are read off directly from the circle, I have, perhaps, from the want of a better, bestowed the above name. The privilege was exercised at the request of Mr. S. W. Burnham, its inventor, who endorses the appellation. I have spent much time and money in its improvement, and have finally succeeded in bringing it to a degree of perfection unanticipated by either the original inventor or myself. Combining clearness with brevity the following is a description of its construction and manner of use. It, together with its several accessories, is shown in the illustration, Plate 2, copied from a photograph. A 15 inch circle of bronze graduated to minutes of time, and read by two verniers to 5s., and by estimation to 2s.. is mounted on a short spindle attached (on a level with the eye) to the north side of the pier, close above the sidereal clock, and carries a grooved iron pulley about a foot in diameter. This, by a small pliant braided cord of fine brass wires, is connected with a similar pulley attached to the polar axis. A weighted rider presses on the cord which maintains the same degree of tension under all temperatures. At first the verniers were propelled by a small clock regulated to sidereal time, but its rate failing to inspire the utmost confidence, the hair spring, escapement, and escapement wheel were removed, and, for the latter. a pin wheel escapement, with 29 pins was substituted. This is connected with a telegraph sounder in electric contact with the break circuit sidereal clock. The vernier clock is propelled as formerly by a spring the sidereal clock simply controlling the velocity of the verniers, which it does with an accuracy equal to its own rate. Above, and to the left of the circle is seen a bottle of shot attached to a metallic cord wound around the shaft on which the verniers revolve. This takes up all lost motion caused by play between the cogs in the clock train. It must be understood that the circle moves at the same rate as the telescope and the verniers keep pace with the sidereal clock and of course with the apparent motion of the celestial sphere.

With this arrangement the approximate R. A. of a new object is quickly obtained in the following manner. At the commencement of work the sounder and driving clock are started, the meridional eye piece wire accurately bisected on a neighboring meantime almanac star and the vernier set to its proper R. A. for a certain epoch, say for January, 1885.0. As my sweeping is generally confined to the meridian, or very near it, places are not vitiated by refraction. By a judicious selection of setting stars a fairly close approximation to the true R. A. of a nebula is read directly from the A. R. A. circle without making a figure for its reduction, save for declination in the usual manner. As the places obtained are purely differential the observer is relieved of all anxiety about the time, the rate of the Howard clock only enters as a function of discordance.

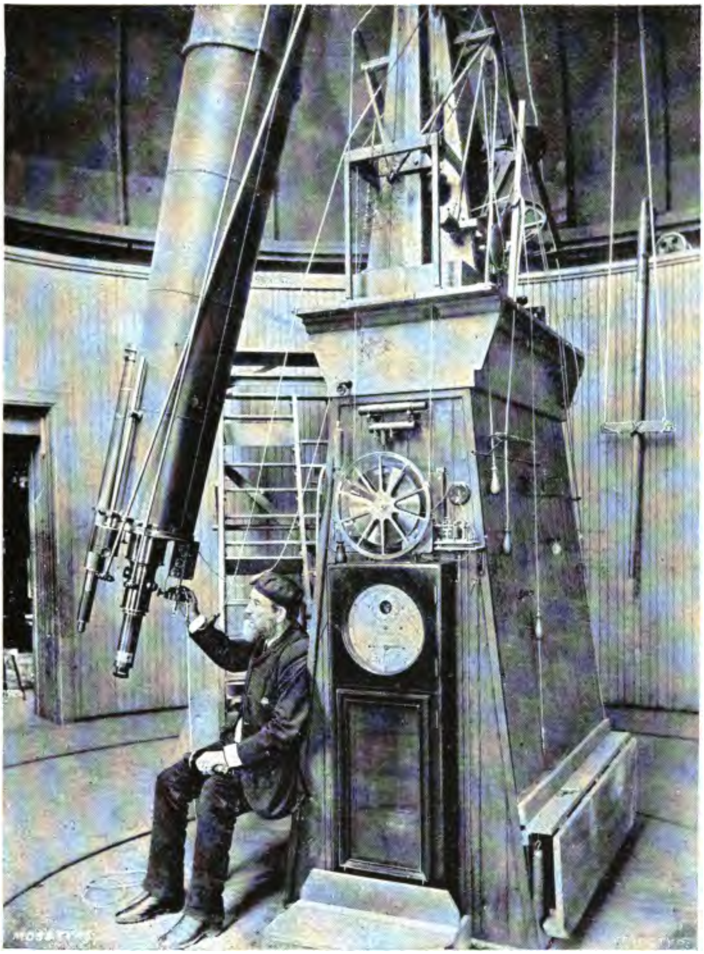


PLATE 1.

General view, showing portions of dome, chair, entrance to little room, and telescope; and, in their entirety, the pier, clock, A. R. A. Circle, and pendant arm by which the dome is revolved.

After a nebula is found three or four minutes suffice to start the driving clock, clamp, bisect, descend from the chair, read both the A. R. A. and dec. circles and write the record. Heretofore I have used apparent instead of mean places for setting stars, but in future the latter will be used, which, owing to the unequal processional and nutational rates in different localities, will give better results.

It is surprising that a contrivance of such utility has not come into general use. Of course absolute precision is not claimed, though the results compare favorably with those made with any equatorial, without the use of a micrometer and comparison star.

THE SOUNDERS.

As before stated the sounder controls the little clock which propels the verniers. The attachment consists simply of a short bar of hard wood, one end of which is bolted to the vibrating arm of the sounder, the other connects with the pin wheel escapement, which liberates a pin at each vibration of the armature, and which, during working hours, is kept constantly going, being attracted to the magnet once in two seconds. By counting both the downward and upward clicks, seconds are indicated which are audible in all parts of the room. Counting these after stopping the driving clock indicates by how many seconds a nebula follows or precedes a certain adjacent star.

This sounder is also made to serve a useful purpose at the transit instrument. By taking in each hand an electrode connected by wires with the coil surrounding the sounder magnet, slight shocks from the secondary current are felt when the primary circuit is broken, and thus a transit may be taken as exactly as though within hearing of the clock beats. The wires in the dome room are concealed in the cracks of the floor. This sounder is therefore made to do a threefold duty.

ALARM SOUNDER.

This is to awaken the observer at moonset or for inspection of the state of the sky. It is placed on a shelf attached to the bedstead of his sleeping room. Wires from the battery go to the break-circuit clock and to the sounder. Looking closely at the clock face in the cut, a false hand held by friction will be seen on the 24 hour arbor, and at the bottom of the circle a metallic spring which the hand (previously set to the proper time for alarm) touches as it passes, and thereby makes connection with the battery. Suppose the moon to set at 2 A. M. and the setting is done at 9 P. M., the hand is simply turned five hours back from the spring, and, at its expiration the alarm sounder commences to beat and will continue for two or three minutes, insuring a thorough awakening of the sleeper.

SIDEREAL CLOCK.

This, the gift to me from a wealthy and generous citizen of this city, Don Alonzo Watson, Esq., was made by the Howard Clock Co., of Boston, and gives perfect satisfaction. It is mounted in a niche in the north side of the pier in the dome room, and is provided with a break circuit.

THE SPECTROSCOPE.

The only instrument of this kind now in use, is a small direct vision star spectroscope, though Alvan Clark & Sons have a contract to construct, at a cost of $1,000, a spectroscope to be used with either prisms or a grating, which is a present to the Director, from Mr. Hiram Sibley, of Rochester.

ENTRANCE TO THE OBSERVING ROOM.

This essential particular is in most observatories treated as a matter of indifference, though no door from any heated apartment ought ever to connect with an observing room. In this case, the entrance is by means of a staircase to the flat roof of the dwelling (where comet seeking is carried on, and where observations of shooting stars, northern lights, etc., are made), and from thence through an ample doorway into the observing-room.

GEOGRAPHICAL LOCATION.

Though circumstances have deferred the determination of the exact geographical position of this observatory (a work which it is hoped will be done in the coming summer), it is assumed to be in Lat. + 43° 8′ 25″, Lon. 5h 10m 23s west from Greenwich, which in future is to be the prime meridian of the world.

WARNER COMET PRIZES.

When the Academy of Sciences of Vienna, Austria, had ceased longer to offer a gold prize medal for each detection of a new comet, Mr. H. H. Warner, the builder and founder of this Observatory, as an impetus to astronomical discovery in this country, offered in 1881 a prize of $200 in gold for every unexpected comet discovered in the United States or in Canada. This offer has, with a few brief intervals, been continued down to the present time. Its last renewal dates from March 1, 1886, and is to extend to March 1, 1887. The offered prize is $100, and is open to the entire world. Olber's comet of 1815, which is at any time liable to reappear, is included in the offer. Following is a complete list of the awards of the Warner astronomical prizes, with the names of the recipients, etc.:

DATE.	DISCOVERER.	AM'T OF PRIZE.	
Oct. 10, 1880,	Swift,	$500.	"Periodic" Special Prize.
May 1, 1881,	Swift,	200.	
July 13, "	Schæberle,	200.	
Sept. 17, "	Barnard,	200.	
Nov. 16, "	Swift,	200.	
Sept. 13, 1882,	Barnard,	200.	
Feb. 23, 1883,	Brooks,	250.	Special Prize.
Sept. 1, "	Brooks,	200.	Comet of 1812.
July 16, 1884,	Barnard,	200.	
July 7, 1885,	Barnard,	200.	
Aug. 31, "	Brooks,	200.	
Dec. 2, "	Barnard,	200.	
Dec. 26, "	Brooks,	200.	
April 27, 1886,	Brooks,	100.	
May 1, "	Brooks,	100.	
May 22, "	Brooks,	100.	
		— $3,250.	

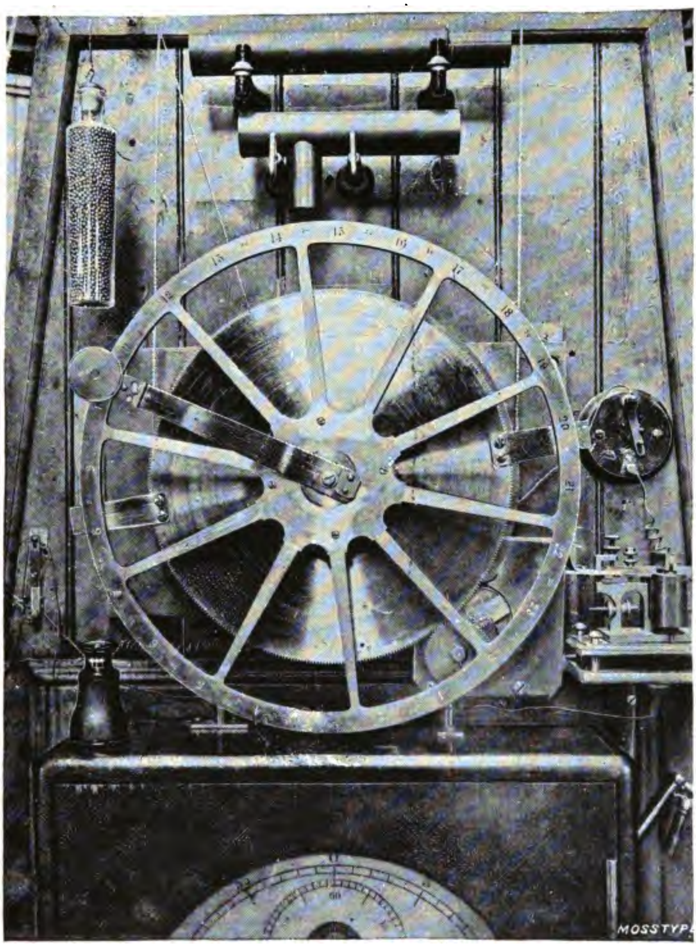


PLATE 2.

Showing A. R. A. Circle, verniers, sounder. vernier clock, star spectroscope, &c.

ESSAYS.

Comet Essay, Boss, - - - - - - - - -		$200.	
Red Skyglow Essay, K. I. Kiessling, Hamburg, Germany, -	200.	1st prize.	
" " " J. E. Clark, York, Eng., - -	150.	2d "	
" " " H. C. Maine, Rochester, N. Y., U. S., -	50.	3d "	
" " " Rev. S. E. Bishop, Honolulu, S. I.,	50.	3d "	
Remuneration to Judges, - - - - -	75.		
	—	$725.	
Total, - - - - - -		$3,975.	

There being a tie between the latter two essayists, Mr. Warner, instead of dividing the prize, gave the full amount to each.

WARNER GOLD MEDALS.

Following are obverse and reverse illustrations of the Warner gold medals for scientific investigation and discovery.

They have been specially awarded as follows, for meritorious essays on the recent sky glows:

Prof. Cleveland Abbe, Washington, D. C.
Prof. Winslow Upton, Providence, R. I.
Prof. H. A. Hazen, Washington, D. C.
Prof. W. M. Davis, Cambridge, Mass.
Frederick Cowle, Lauriston, River Forth, Tasmania, Australia.
Rev. Robert Graham, L.L. D., Errol, Scotland.
Dr. Charles Braun, Mariaschein, Bohemia.

The judges were: Prof. Daniel Kirkwood, Bloomington University, Ind.; Prof. M. W. Harrington, University of Michigan, and Prof. Ormond Stone, University of Virginia.

When, also, the building and maintenance of an observatory is considered, it must be generally conceded that Mr. Warner has been a liberal patron of science. The American Association for the Advancement of Science, appreciating this, in the year 1882 made him a member of that Society.

DISCOVERY OF NEBULÆ.

The subjoined catalogues of nebulæ embrace those discovered at the Warner Observatory since July 9th, 1883. There have been. however, reserved for re-observation and the assignment. of more accurate places, nearly one hundred others. In order that the non-professional astronomer may intelligently read the descriptions, a partial list ot abreviations, from Sir John Herschel's General Catalogue, and words for which they stand, are first given.

an. another.
B. bright.
b. brighter.
bet. between.
c. considerably.
diff. difficult.
D. double.
e. exceedingly.
E. elongated.
f. following.
F. faint.
G. C. General Catalogue.
H. Sir Wm. Herschel.
h. Sir John Herschel, hours.
i. irregularly.
inv. involved.
l. little.
L. Large.
m. much, minutes of time, magnitude.
M. Messier, middle.
n. north.
neb. nebula, nebulous.
neby. nebulosity.
np. north preceding.
nf. north following.
nr. near.
p. pretty, preceding.
R. round.
s. south, seconds of time.
s. p. south preceding,
s. f. south following.
st. stars.
sev. several.
S. small.
v. very.
* star.
▽ a triangle.
° degrees.
′ minutes of arc.
″ seconds of arc.

851, 582, 5251, etc., refer to numbers in Sir John Herschel's General Catalogue of Nebulæ.

CATALOGUE NO. 1 OF NEBULÆ DISCOVERED AT THE WARNER OBSERVATORY.

The places given are for 1885.0 and though only approximate, the nebulæ will, I think, be found very near the positions assigned. About a dozen were discovered by my son, then a lad of thirteen years. They are marked "Edward". All have north declination except those indicated by the minus sign.

The eye-piece used is a periscopic positive, made especially for the work by Gundlach of this city. It gives a power of 132, and the astonishingly large field of 33′.

No.	Date of Discovery.	α 1885.0	δ 1885.0	DESCRIPTIONS AND REMARKS.
1	1884 Aug. 8	0h 4m 32s	28°21′ 5″	e F; v S; E; B * nr.
2	1884 Oct. 9	2 2 35	7 25 0	v F; p S; e E; spindle; cannot be G. C. 493, is not "am st," nearest * is 5′ distant. Did not see 493, but saw 5223 H. desciption must apply to some other nebula.
3	1884 Nov. 9	2 27 22	9 13 46	v F; c E.
4	" " 9	2 45 2	−2 13 6	F; v E.
5	1884 Oct. 18	3 1 31	40 27 0	S; R; e F. Right angled with 2 st. In field with Algol.
6	" " 14	3 1 32	38 11 20	e F; l E; v diff.; F * close n.
7	1883 Nov. 24	6 26 36	10 23 15	Nebulous *; v diff.; B * exactly in center of L e F nebulosity; f, 1425 28s and is 10′ n. Resembles 4634 in Cepheus, but is fainter.
8	1885 May 11	9 23 20	68 7 45	p F; p S; R; l b M.
9	1883 Aug. 24	10 49 5	18 13 30	p B; R; no * nr.
10	" " 24	11 4 25	22 21 30	e e F; v S; R; diff.; s. of 2.
11	" " 24	11 4 35	22 22 0	v F; R; n. of 2.
12	1883 April 26	11 8 4	21 1 0	c S; v F; f. δ Leonis 4s. Easily overlooked.
13	1885 April 13	11 38 40	20 8 42	v F; v S; R; B * 12s f; np. of 2.
14	" " 13	11 38 45	20 3 42	e e F; R; p S; B * nf; sf. of 2.
15	" " 13	11 39 10	20 0 27	v F; S; l E; 8 mag. * in field.
16	" " 13	11 39 10	20 12 37	v F; p S; R.
17	" " 10	11 43 45	12 42 43	F; v S; R; m b M.
18	" " 16	11 50 15	56 1 40	e F; p L; p E; v diff.; D neb. nr.
19	" " 6	11 54 40	20 2 35	p F; p L; R; n. of 2 st. which form with it a right angle triangle.
20	1884 June 18	11 59 1	65 5 40	S; F; v E; D * nr.
21	1885 April 6	12 5 0	19 39 35	e F; v S; p. nearest B * east 20s.
22	1884 Mar. 16	12 28 32	51 26 54	e e F; S; R; nearly bet. 2 st.
23	1885 June 14	13 13 45	40 12 20	p F; R; p L; DM. north 40°2644-5 point to it.
24	1885 April 6	13 34 30	−23 18 9	e F; p L; p. by 6s the middle * in a line n and s.
25	" " 10	13 43 10	−29 58 56	e F; p S; l E; v F * f; p. diff.
26	1884 June 16	13 53 3	46 53 9	F; v S; to nu. * v close.
27	" " 16	13 57 0	49 0 28	e F; S; l E; B * 4′ n; 2 coarse D * in field.
28	1883 July 9	13 57 38	46 52 26	v F; p L; c E; bet. 2 st. forming with 2 others a trap., the nf. being a fine D * of 2″.5. First neb. discovered at this Observatory. I have not been able to see this object well since its discovery, at which time I called it p B with p sharp outlines, but since the appearance of the red sunsets it has been ill defined and difficult to see except as a hazy spot. This remark applies to all v F nebulae.* The D * is new.
29	1885 May 9	14 6 5	60 59 16	e e e F; p S; R; e e diff.; bet. 2 st. one a wide double. Edward.
30	" " 11	14 6 12	60 56 45	e e e F; v S; R; e e diff.; forms with 2 st. a right angle triangle.
31	" " 11	14 13 50	59 16 50	e F; p S; R; F * nr. west.
32	1884 June 14	14 14 0	7 34 4	S; e F; l E; 2 F st. point to it; 3 others nr,; v diff.; np. of 2.
33	" " 14	14 14 31	7 33 4	S; e F; sf. of 2; v diff.; a * midway bet. them.
34	" " 14	14 14 31	7 32 34	S; e F; R; v. diff.
35	1884 May 22	14 15 30	6 44 5	v S; l E; v F; m b M. to nu.
36	1885 June 22	14 33 35	52 3 54	B; p S; R; p. DM. north 52°1816 31s. Found in presence of a half moon. First found 7 years ago with 4½ inch Comet seeker and recorded as "can find no record of it."
37	1885 May 14	14 45 50	47 51 40	e F; p S; R; * nr.; saw another nr. as I supposed, but could not refind it.
38	1885 June 9	14 49 0	56 23 20	v F; p S; l E; l B M; p B * nr.
39	" " 9	14 56 30	55 57 20	v F; E; p L; * nr.; 4058 in field.
40	" " 11	15 3 0	56 2 20	e F; p S; R; v diff.; 3 st. in a line point to it; 4058 nr.
41	" " 11	15 3 30	55 55 20	e e F; p S; l E; e diff.; p. a B * 7s; 4058 in field.
42	" " 11	15 4 35	55 11 45	v F; p L; R; in center of a L equilateral triangle of 3 B st.
43	" " 11	15 6 10	54 57 0	F; S; m b M; R.
44	1884 June 15	15 18 30	13 8 15	F; v S; forms a right angle triangle with 2 st.
45	1883 July 11	15 24 0	69 8 13	p B; l E; p S.
46	1884 May 21	16 25 0	20 25 27	e e F; v E; F * at p. end; v diff.
47	1884 Aug. 2	16 39 5	66 15 51	v F; S; R; coarse D * in field north.
48	1884 June 28	16 44 8	70 50 28	p F; p L; l E. 1st of 4.
49	" " 28	16 45 9	70 58 58	F; p L; B * nr. 2nd of 4.
50	" " 28	16 45 10	70 50 28	e F; E; S. 3rd of 4.
51	" " 28	16 46 30	71 0 28	v F; p L; R. 4th of 4.

No.	Date of Discovery.	α 1885.0	δ 1885.0	Descriptions and Remarks.
52	1884 Aug. 19	16 58 0	68 37 54	c F; v S; R; v F * nr.; sp. of 2. Edward.
53	" " 19	16 58 30	68 40 0	c F; c E; p L; 2 B st. nr. n.; nf. of 2. Edward.
54	1884 Oct. 14	17 5 0	68 30 25	c F; c E; p L; nearly bet. 2 st.
55	1883 June 2	17 8 14	63 2 30	e c F; S; R; F * nr.; sp. of 2.
56	1885 May 14	17 8 20	68 6 45	v S; v F; R; l b M; nf. of 2.
57	1885 April 19	17 21 20	57 4 50	v S; v F; R; B * nr. n.
58	1885 June 13	17 22 30	59 6 10	e e e F; p L; e diff.; forms a right angle triangle with 2 st., p. * in same parallel 30s distant.
59	1885 July 7	17 25 45	60 6 2	v F; p L; E; DM. north 60°1754 much interferes with visibility.
60	1883 June 2	17 25 59	56 57 20	p F; p S; R; * near.
61	" " 8	17 26 29	52 48 20	v F; p S; R; bet. 2 st.
62	1885 July 7	17 26 50	60 17 5	e e e F; c E; e e diff.; one of my minima *visibile*.
63	1884 Sept. 18	17 28 30	71 10 43	v F; p L; l E; D * n; 2 st. nr. point to it. Edward.
64	1885 July 7	17 28 45	59 43 32	e F; p S; R; 2 B st. nr. n; s. of 2.
65	" " 7	17 28 45	59 47 3	e F; p S; R; 2 st. point to it, the nearer is D; the other and the neb. are equally distant from D *; n of 2.
66	" " 7	17 30 10	59 41 17	e F; v S; R.
67	1885 June 18	17 33 20	50 50 8	v F; S; R. [Edward.
68	1885 May 4	17 36 33	58 47 45	e F; p S; R; forms a right angle triangle with 2 st., one m b.
69	1885 April 19	17 41 50	56 51 20	v F; p S; R; B M.
70	" " 19	17 42 30	55 45 20	v F; p S; R; l b M.
71	1885 June 8	17 42 45	66 31 30	F; v S; R; B M.
72	1885 April 19	17 43 40	55 49 22	e F; e S; R; e diff.; stellar. May be a few e F st.
73	1885 June 5	17 43 58	61 58 0	F; e S; R; planetary.
74	1884 Sept. 18	17 44 30	60 57 30	e e e F; R; p S; e e diff.; s of 4 st. in form of a square.
75	" " 18	17 45 0	51 25 33	e F; v S; R; bet. 2 st. which with 2 others forms a cross like cross in Cygnus. Neb. placed as is γ Cygni.
76	1885 April 20	17 46 5	54 11 40	p S; e F; R; 3 st. n. point to it, the n one the brighter.
77	1885 June 5	17 48 5	60 6 10	e e e F; p L; l E; bet. 2 st.; e e diff.; coarse D * s.
78	" " 13	17 48 40	61 33 40	e S; p F; v F * in or just in contact with it; np. of 2.
79	" " 5	17 48 55	61 32 20	F; e S; R; planetary; F * v nr.; sf. of 2.
80	1884 Sept. 16	17 49 30	59 31 17	e F; p S; l E; diff.; close s of middle * of 3 in a line, middle * the fainter; np. of 2.
81	" " 26	17 49 31	59 30 45	p F; p S; R; B * nr.; F * v nr.; sf. of 2.
82	1884 June 17	17 52 30	72 1 58	S; v F; forms with 3 st. a square.
83	1884 Oct. 9	17 53 40	60 49 33	F; p L; B M; 2 nearest of 3 st. in a curve point to it.
84	1884 Aug. 18	17 57 0	64 55 57	v F; R; p L; 3 st. in form of a triangle nr. Edward.
85	1885 June 8	18 3 8	56 14 55	F; p S; B M; R; bet. 2 st.
86	" " 14	18 8 25	61 24 0	v F; v S; R; nearly bet. 2 st. 1st of 8.
87	" " 14	18 8 50	61 6 45	v S; v F; R; bet. a F and a more distant B *. 2nd of 8.
88	1883 Sept. 6	18 9 40	69 1 45	e F; p S; R; in vacancy; 3 st. in a curve south.
89	1885 June 14	18 9 50	61 9 15	v S; R; v F; diff. by proximity to a B *. 3rd of 8.
90	1883 Aug. 4	18 10 20	61 25 15	e F; R; p S; nr. end of a curve of st. 4th of 8.
91	" " 4	18 10 45	61 18 5	e F; p S; R; v diff. 5th of 8.
92	" " 4	18 11 0	61 18 15	e S; R; v F; v F * nr. 6th of 8.
93	" " 4	18 11 5	61 18 15	v F; l E; p S; F * nr. 7th of 8.
94	1885 June 14	18 12 40	61 16 45	e e e F; p L; R; e e diff.; in vacancy. 8th of 8.
95	" " 2	18 13 52	68 19 20	p F; p S; l b M; R; n of 2. Edward.
96	" " 2	18 13 52	68 19 5	p F; p S; R; l b M; s of 2.
97	1883 Sept. 11	18 26 50	73 6 15	p B; R; m b M. Looks like a comet.
98	1885 June 8	18 33 25	67 3 10	p F; p S; R.
99	" " 8	18 33 30	67 45 30	p F; p S; R.
100	1883 July 11	18 36 0	59 33 17	e F; p L; R; bet. 2 st., also bet. 2 coarse clusters np. of 2.

CATALOGUE NO. 2.

No.	Date of Discovery.	α 1885.0	δ 1885.0	Descriptions and Remarks.
1	1885 Sept. 20	0h 0m 23s	31° 50′ 2″	e F; v S; e E; B*s; v F* v nr.
2	" " 20	0 0 52	32 17 40	e F; v S; R; bet. 2 st.
3	" " 20	0 2 22	31 52 47	e F; c E; v S; one of 5 st. which point to it is p nr.
4	" " 20	0 3 30	32 12 47	e e F; l E. in center of 3 v F st. forming an equilateral triangle, two of them double.
5	" " 20	0 3 42	32 34 17	e F; S; l F.
6	" " 7	0 8 45	47 36 30	c e F; p L; R; e diff. 1st of 3.
7	" " 7	0 8 55	47 37 0	c e e F; S; R; middle one of 3 in a line. 2nd of 3.
8	" " 7	0 9 5	47 36 45	p F; p S; R; B M. 3rd of 3.
9	" " 17	0 20 50	31 4 15	c F; v S; R; forms right angle triangle with 2 *
10	" " 17	0 42 50	31 19 45	c F; v S; R; v diff.
11	1885 Oct. 1	0 51 40	48 11 25	e e F; l E; p S; i R; D* close f; v diff.
12	1885 Sept. 6	1 1 30	39. 6 33	e F; e S; R; * nr.
13	" " 17	1 36 10	12 0 50	p B; p L; v E; nearly bet. 2 p B st. If this is Stephan's No. 1 of his Catalogue of 60 nebulae, A. N. 2390, then his description is wrong in every particular.
14	" " 17	1 41 10	12 32 37	e F; p S; R; bet. a D* and a * with a distant companion.
15	" " 12	1 50 50	44 21 30	v F; p S; l E; several st. nr.
16	1885 Oct. 9	1 56 50	— 0 38 45	e e F; p S; R; n. of 2.
17	" " 9	1 56 50	— 0 41 0	c e F; S; R; s. of 2.
18	1885 Sept. 20	1 57 10	37 43 10	c F; p S; i R; D* close f; v diff.
19	" " 7	1 57 45	30 16 45	c e F; v S; R; l b M; v diff.
20	" " 11	2 21 10	45 27 5	e F; e S; R; 1 or 2 e F* close; e diff. Powers 132, 200 and 265.
21	" " 11	2 21 50	45 24 0	c F; e S; R; B* nf; e diff. Powers 132, 200 and 265.
22	" " 18	2 21 50	19 4 29	p B; p S; R; p. a p B* 6s.
23	1885 Aug. 16	2 38 50	39 36 38	v F; p L; E.
24	" " 20	2 40 48	40 46 2	v F; p S; D* nr.
25	1885 Sept. 6	2 45 28	41 44 0	v F; p S; R; * nr n.
26	" " 12	2 56 35	42 57 0	p F; p S; R.
27	" " 12	2 58 35	43 36 45	p F; c E; p S; sev. v F st. nr.
28	1885 Aug. 20	3 3 43	40 56 0	c F; v S; R. Components of a nr D* point to it.
29	" " 20	4 5 12	27 24 30	v F; p L; R; l b M.
30	1884 Nov. 24	5 1 5	— 3 29 45	Nebulous*; e F; p S; R; p. G. C. 1005 6s and is about 1′.5 n. of it. G. C. 1005 is also a nebulous * = H. V 32, which Auwers describes as being nr. and s. f. a B*. This B* is the above nova.
31	——	6 24 11	5 7 32	p B; e L; l E; H. VII; 2 near = G. C. 1424.
32	1885 Sept. 7	8 1 35	73 56 11	p B; p L; l E; l b M; * nr. Edward.
33	" " 7	8 8 0	74 19 11	e e F; p S; R; sev. B st. nearly surround it.
34	" " 7	8 11 0	74 22 11	e e F; p S; c E; bet. an e F*, and an unequal D*.
35	" " 7	8 11 30	73 46 41	p F; v S; R.
36	1885 June 14	13 45 50	38 51 20	c e F; p S; R; v diff.; 2 B st. nr.
37	1885 Aug. 5	15 32 5	56 50 10	e S; R; stellar.
38	" " 5	15 32 45	56 50 12	e e F; v S; R; l b M. In field with G. C. 4114–15.
39	1885 July 8	16 8 15	70 12 29	v F; v S; R; * nr n.
40	——	16 15 33	62 12 45	p F; v S; E; * nr.
41	1885 Aug. 3	16 29 45	59 51 30	v F; p S; l E; v coarse D* nr., forming with it an equilateral triangle.
42	1883 Oct. 30	16 30 0	58 40 55	v F; p S; R; F* nr.
43	1885 Aug. 16	16 41 30	61 47 54	p B; v S; R.
44	" " 11	16 47 0	70 33 0	c e F; p L; R; bet. a B* and 3 st. in a line; v diff.
45	" " 13	16 56 40	59 6 45	e F; p S; R.
46	" " 13	16 59 0	59 8 15	c F; p S; R; * nr f; 2 B st. nearly point to it. n. of 2.
47	" " 13	16 59 0	59 6 15	e e F; e S; R. s. of 2.
48	1885 July 8	17 1 10	61 12 3	c F; E; sev. v F st. nr.; v diff.
49	" " 8	17 2 5	62 11 5	p B; p S; R; bet. 2 st.; sp. of 2.
50	1885 Aug. 1	17 2 10	62 11 10	v F; e S; R; bet. 2 st.; nf. of 2.
51	1885 July 8	17 6 11	60 52 5	v F; v S; l E. Close to 4278. sp. of 2.
52	" " 8	17 6 28	61 7 30	p F; v E; 3 st. in line point to it; nf. of 2.
53	1885 Aug. 1	17 16 30	61 54 10	v F; v S; R; forms arc of circle with 2 st., neb. between.
51	1885 Sept. 11	17 19 40	29 20 45	p F; v S; R; F* close; stellar.
55	1883 Aug. 17	17 36 20	68 13 35	e e F; e S; R; e diff. n. of 2.
56	" " 17	17 36 20	68 6 50	c c F; e S; R; e c diff. s. of 2.
57	" " 1	17 36 40	68 7 20	e F; p S; R; nearly bet. a F and a B*.
58	" " 1	17 37 10	68 13 20	c e F; v S; R; * nr. east; v diff.
59	1885 Aug. 5	17 37 10	70 3 0	v F; p S; R.
60	1883 July 16	17 41 55	53 35 13	v F; p S; R; l b M.
61	1884 July 1	17 42 30	18 37 0	v F; v S; B* f. 8s; bet. 2 st.
62	1885 July 12	18 9 30	—19 55 1	A nebulous D*; p F; sf. of 2. A D* in center of a p F, p L circular atmosphere each * of the 8.5 mag. and about 20″ distant. A wonderful object, not diff.
63	1885 July 12	18 9 28	—19 50 1	Another D* in center of an e F, p L nebulosity; np. of 2. Except the inequality of the stars and the excessive faintness of the nebula, it would resemble the preceding.
64	" " 14	18 13 15	22 11 18	v F; e S; e E; forms S. equilateral triangle with 2 F st.
65	1885 Aug. 11	18 13 40	68 13 57	v F; p S; R; s. of 2. Double.
66	" " 11	18 13 40	68 14 7	v F; p S; R; forms an e c. close double with the preceding. Very difficult to separate with a power of 265. Well seen.

No.	Date of Discovery.	α 1885.0	δ 1885.0	Descriptions and Remarks.
67	1883 Sept. 11	18 25 45	67 56 15	v F: v S; R; 2 st. range with it.
68	1885 July 14	18 29 45	22 39 33	p B; p S; R; m b M; bet. 2 st. Larger and b than 5918.
69	1883 Sept. 11	18 30 50	67 54 15	v F; p L; l E; v F D* nr.
70	1884 June 17	18 39 30	59 15 45	e e e F; in vacancy p L; sev. B st. f. and p. it; e diff.
71	1883 Aug. 6	18 41 45	60 32 17	p B; p S; v E; F* close to f. end.
72	1885 Aug. 5	18 45 45	47 31 5	v F; p S; R; l b M.
73	1885 Sept. 10	18 58 50	59 0 15	v F; v S: R.
74	1884 Aug. 15	19 2 25	55 32 12	p F; v E; 3 v F st. curiously placed in it on the line of major axis which also point to a D*.
75	1884 April 30	19 4 30	63 44 50	e F; v E. s. of 2
76	1883 Aug. 30	19 4 30	63 45 20	e F; v S; c E; F* nr; D* in field. n. of 2.
77	1885 July 4	19 5 20	50 44 53	p F; p L: c E; sev. v F st. involved.
78	1885 Sept. 10	19 14 20	60 13 0	e e e F; p S; 4 st. in semi-circle sf.; e diff.
79	1885 July 5	19 19 45	60 55 17	v F; p S; v E in meridian.
80	1885 Aug. 5	19 21 15	53 23 25	F; v S; R; * v nr; in field with 51 Draconis.
81	1885 Sept. 10	19 35 45	62 7 45	e e F; p S; l E; a curve of st. w. like Northern Crown.
82	1884 Sept. 18	19 41 0	63 47 30	e F; v S; F* nr.; v diff. Edward.
83	1884 Aug. 26	20 0 5	65 55 15	p B; R; p S; 2 B st. and it form an arc of a circle.
84	1885 June 9	20 18 30	66 22 10	e F; L; l b M; p B* nr.
85	1885 Sept. 14	20 35 35	65 42 12	p B; p L; l E. Discovered many years ago with 4½ inch.
86	" " 14	20 36 28	65 21 42	e e e F; p L; R; e e diff.
87	" " 11	21 0 10	11 0 50	p F; p S; R; l b M.
88	1884 Oct. 10	21 30 45	12 15 54	Nebulous*; B*; in e e F nebulosity; v diff.; nearly pointed to by 3 st. in a line.
89	" " 18	21 42 0	9 42 20	v F; p L; l E; bet. 2 st.; 5 st. w. in form of a pyramid.
90	1884 Nov. 9	21 58 2	12 6 40	v F; S; R; l b M; s. of 2.
91	" " 9	21 58 2	12 7 40	e e F; R; v diff.; n. of 2.
92	" " 18	22 35 10	— 5 0 34	v F; p S; R.
93	" " 15	22 47 0	— 9 51 32	e F; p L; mistaken for Barnard's Comet 1884 II. [Pegasi.
94	1885 Oct. 31	22 52 37	13 41 22	e e F; L; R; F* nr nf.; v diff. Nearly in finder field with *a*
95	1884 Oct. 14	22 55 20	6 7 42	e e e F; p L. R; e diff.; np. of 2. [Comet 1885 I.
96	" " 14	22 55 30	6 40 42	e F; c E; p S* nr p. Found while searching for Encke's
97	" " 14	22 55 40	6 7 40	e e F; p L; R; * nr. sf. of 2.
98	1885 Oct. 31	23 3 5	11 25 49	e F; l E; S; 9m* close nf.
99	1884 Oct. 10	23 6 30	30 29 43	B; p L; R; B M. Easy in presence of a half moon.
100	1885 Oct. 31	23 21 40	11 45 4	e F; p S; R; v diff.; G. C. 4966 near; H. is wrong and h. right as to brightness of 4966.

CATALOGUE NO. 3.

No.	Date of Discovery.	α 1885.0	δ 1885.0	Descriptions and Remarks.
1	1885 Nov. 10	$0^h 18^m 5^s$	15°50′40″	v F; p S; v E.
2	" " 10	0 41 35	7 16 12	e F; v S; R; in center of 3 st. in form of a triangle.
3	" " 10	0 56 18	− 2 33 49	e F; p S; np. of 2.
4	" " 10	0 56 40	− 2 35 21	e F; p S; R; sf. of 2.
5	" " 30	1 21 51	47 47 30	e F; p S; R; D * nr. s.
6	" " 30	1 26 10	− 7 28 50	v F; p L; R; sf. of 363. 351 in field.
7	" " 30	1 26 43	35 4 0	e F; p S; R; B * nr. sf.
8	1885 Dec. 2	1 58 5	− 0 2 47	e F; p S; R; B * 32^s f.
9	1885 Nov. 30	2 5 6	44 2 15	v F; p L; R; nearly bet. a p B and 3 v F st. in line v nr. together.
10	" " 30	2 5 25	3 13 53	e F; p S; R; v diff. Edward.
11	1885 Dec. 2	2 20 30	11 38 18	v F; v S; R; in vacancy.
12	1885 Nov. 7	2 22 40	31 7 16	v F; e S; R; v diff. 5239 near.
13	1885 Oct. 17	2 30 50	1 33 32	e e F; p S; R; bet. a p B * and a F D *. Not 5251, 5264 nor 602.
14	" " 17	2 31 40	1 28 17	e e F; e S; p F * close.
15	1886 Jan. 1	2 32 6	1 48 32	e e F; p S; R; * 9 m sf.; v diff. Edward.
16	1885 Oct. 17	2 34 15	1 0 50	e e F; p S; R.
17	1885 Nov. 10	2 34 48	− 8 56 25	e e F; L; R; np. of 2.
18	" " 10	2 35 0	− 9 2 26	e e F; p S; R; sf. of 2.
19	" " 10	2 35 0	− 8 39 25	e e e F; p S, R; e diff.; G. C. 582, 589 in field; np. of 2.
20	1885 Dec. 29	2 38 10	−15 14 50	v F; p S; R; B * 22^s f.
21	" " 2	2 42 30	−14 26 45	e e F; S; l E; 11^m * close f.: 16^m * involved.
22	1885 Oct. 17	2 48 15	2 28 30	v F; p S; R; l b M.
23	1885 Nov. 10	2 51 55	− 8 13 40	e e F; S; R; * nr. s.; v diff.; sf. of 2.
24	" " 10	2 51 23	− 8 9 40	e F; p S; R; v diff.; np. of 2.
25	" " 10	3 12 18	− 8 3 10	e F; e S; R; 4 B st. in form of arc of circle close south.
26	" " 10	3 22 30	− 8 47 56	v L; v E nearly in meridian; e F.
27	1886 Feb. 24	3 48 0	68 17 5	v F; v S; R; B * near.
28	" " 24	3 52 36	70 43 55	e F; p S; R.
29	1885 Nov. 10	4 20 50	−10 22 29	v F; p L; R; * nr. south.
30	1885 Dec. 29	4 28 50	− 8 49 55	S; p F; R.
31	" " 15	4 39 22	− 8 41 24	e e F; e e diff.; nf. of 895.
32	" " 2	4 53 50	−11 18 14	e F; v S; R; v diff.; 1st of 3. Tempel's $4^h 58^m 52^s$—11°9′24″ in field.
33	" " 2	4 54 5	−11 18 29	e e F; v S; R; e diff.: 2d of 3. " " " " "
34	" " 2	4 54 15	−11 18 14	e F; v S; R; v diff.; 3d of 3. " " " " "
35	" " 9	5 5 30	5 3 42	v F; S; R.
36	1886 Feb. 27	6 26 20	5 11 53	e e F; L; i R; v diff. Probably an off-shoot of No. 31 of my Catalogue No. 2. Two or three others suspected.
37	1885 Nov. 15	7 52 10	8 18 30	e e e F; p S; i R; B * nr. w.; sp. of 2; e diff.
38	" " 15	7 52 25	8 19 15	v F; p S; R; * close east; nf. of 2.
39	1886 March 9	8 29 50	− 1 27 38	v F; S; R; * nr. nf.
40	1886 Feb. 8	8 40 30	−33 25 10	p F; p S; l E.
41	1886 Mar. 10	8 46 30	− 2 11 20	p F; S; p E.
42	1886 Feb. 27	8 50 20	− 2 8 8	v F; p S; v E; * nr. f.
43	" " 8	9 14 40	− 7 24 22	p F; p S; R.
44	" " 27	9 15 10	−16 1 36	e F; p S; v E; 1829 and Rosse's nova 1828 in field west. Did not notice 1819 east of 1829.
45	" " 9	9 20 16	−11 30 35	e F; p S; p a coarse D * 17^s. In field with 1854.
46	1886 Mar. 10	9 24 20	4 37 59	e e F; p L; R; in vacancy.
47	" " 10	9 37 22	− 9 14 32	e F, S; R; s. of 2. 1908 in field near.
48	1886 April 21	9 42 45	32 43 55	e e F; e s stellar. A row of 8 or 10 p B st. nr. p.
49	1886 Mar. 10	9 43 20	1 7 55	v F; p S; l E; * nr. north; p. of 2.
50	" " 10	9 43 35	1 7 55	p F; p L; c. E.; an. nr. p. f. of 2.
51	1886 May 22	9 44 25	29 4 0	e F; p S; l E in vacancy. Found searching for Winnecke's comet.
52	" " 27	9 46 15	−32 13 34	p B; p S; R.
53	" " 27	9 56 25	−31 7 50	e F; p L; R; v coarse D * nr. p.; 2002 in field.
54	1886 April 2	10 20 20	− 2 3 29	v F; S; l E; bet. a p B and a v F *.
55	" " 27	10 22 15	13 16 18	v F; p S; R.
56	1886 March 5	10 26 45	−21 42 46	e F; v S; middle one of 3 e F st. inv. 2 B st. point to it.
57	" April 27	10 31 0	13 13 18	F; S; R; sf. of 2147.
58	" March 5	10 54 5	18 11 38	e e F; p S; R; e diff.; in vacancy.
59	5	11 0 15	20 42 10	p F; v S; l E; in starless field.
60	" " 5	11 16 15	21 19 55	e F; S; R; bet. 2 st.
61	1886 April 27	11 50 15	− 2 6 14	p B; v S; R.
62	1885 Nov. 14	11 50 20	56 1 59	e e F; p S; R; v diff.; 2618-19-34-35 in field.
63	" April 27	12 11 40	−10 40 57	p B; e S; p B * nr. p. Looks at first like a D *. Curious object.
64	1885 May 6	12 13 45	−11 37 5	v F; p S, R.
65	1885 Oct. 30	12 14 0	51 59 5	p B; E. 1 or 2 v F st. in middle. Looks like a comet. Edward.
66	1886 Oct. 6	12 14 25	−11 4 8	e e F; v S; R. 1st of 3.
67	" " 6	12 14 30	−11 3 33	e e e F; v S; R. 2nd of 3.
68	" " 6	12 14 43	−11 0 33	e F; p S; R. 3rd of 3.
69	1886 June 8	13 12 50	−11 58 10	e e F; e S; v F * v close. Looks like a F D * at first. H. III, 117 and 118, II 193, R nova, and G. C. 5780 in field.
70	" " 8	13 14 50	−11 54 40	e F; e S; R; stellar, nearly bet. 2 st.
71	" " 8	13 15 15	−12 28 55	e F; e S; R.
72	" " 8	13 15 43	−12 27 20	e F; p S; l E; 2 D st. in field.
73	" " 8	13 16 45	−12 24 10	e F; p S; R; in line with 2 p B st.

No.	Date of Discovery.	α 1885.0	δ 1885.0	Descriptions and Remarks.
74	1886 Jan. 1	13 29 25	48 30·5	e F; L; v E; v diff.
75	1886 Mar. 29	13 31 15	— 7 54 58	p F; e S; v F* v close.
76	1886 April 8	13 44 25	70 54 18	e S; stel.; v F; e F* v close. Components of a D* point to it.
77	1886 May 6	13 47 5	73 12 33	e F S; R.
78	" " 6	13 48 20	74 29 35	v F; S; R.
79	1884 June 8	13 55 30	74 8 50	p F; S; R; D* nr. p.
80	1886 April 8	13 55 45	71 17 48	e F; v S; R; forms equilateral triangle with 2 st.
81	1884 June 11	14 2 2	66 14 59	e F; v S; R nearly bet. 2 st.
82	1886 June 6	14 6 55	13 49 22	v F; p S; bet. a single and a D*.
83	" " 4	14 16 15	13 44 22	v F· p S; R; p B* nr.; also a faint one; np. of 2.
84	" " 4	14 16 35	13 42 37	e F v S; R; nearly bet. 2 B st. sf. of 2.
85	" " 4	14 16 55	14 12 22	e F· S; R; p B* nr. sf.
86	" " 6	14 41 25	14 7 22	e F; p S; bet. a single and a D*.
87	1886 May 22	14 43 25	12 55 20	v F· S; R; p of 2.
88	" " 22	14 43 50	12 57 20	e e e F; p S f of 2; e e diff.
89	1886 June 20	14 49 5	19 7 4	e e e F· p S; R; p B* close f.; e e diff.
90	" " 20	14 56 45	19 8 49	e e F; p S; l E; p B* close f.
91	" " 28	15 51 20	65 11 53	e e e F; S; R, e e diff. D* points to it.
92	" " 28	15 52 5	65 15 38	p F; p S; R; B M* close; forms s. △ with 2 st.
93	" " 19	15 58 18	17 32 30	e e e F; v S; R; e e e diff.
94	" " 27	15 59 15	18 0 40	e e e F; v S; R; s. p. of 3 in a line. *See Note.* 3rd of 10.
95	" " 27	15 59 38	18 6 3	e e F; l E; p S. 4th of 10.
96	" " 27	15 59 40	18 12 3	e e F; v S; R; v F* nr. p. 5th of 10.
97	" " 27	15 59 45	18 5 3	e e F; v S; R, v diff. 6th of 10.
98	" " 27	15 59 50	18 2 33	e F; R; p S. F* close north. 7th of 10.
99	" " 27	16 0 0	18 4 33	e e e F; S; R; e diff. 8th of 10.
100	" " 27	16 0 15	18 5 28	e e e F; p S; l E; F* v nr. sp. 9th of 10.

Note.—Three of the ten or more nebulæ in this interesting group are M. Stephan's, presumably G. C. 5799 and certainly 5800 and 5801. Two or three more are suspected. They are very difficult objects to see and especially to measure, atmospheric conditions seldom allowing them to be seen at all except Stephan's last two, which are quite interesting objects, but those he describes as faint and small and very faint and very small, I call pretty large.

CATALOGUE No. 4.

No.	Date of Discovery.	α 1885.0	δ 1885.0	DESCRIPTION AND REMARKS.
1	1886 June 8	16h 0m 15s	18°26′58″	e e e F; S; R; e e diff. 1st of 4.
2	" " 8	16 0 20	18 26 58	e e e F; S; R; e e diff. 2nd of 4.
3	" " 8	16 0 25	18 14 57	e e e F; p S; R; e e diff. 3rd of 4.
4	" " 6	16 1 3	18 33 0	e e e F; S; R; e e diff. 4th of 4. 4 B st. with the neb. form a cross-like cross in Cygnus: neb. placed as is Deneb Cygni.
5	" " 8	16 1 5	— 6 6 17	v F; S; R.
6	" " 6	16 8 0	18 3 15	e e e F; p S; e e e diff.; R.
7	1886 May 22	16 9 15	61 32 4	e F; p S; R; in line with 2 st.
8	1886 July 3	16 10 52	1 9 22	e e F; v S; a B and a F * nr. np. point to it, an e e F * close p; [e e diff.
9	" " 6	16 17 0	58 15 45	e F; v S; R. 1st of 3.
10	1886 June 28	16 17 6	58 16 20	p F; p S; R; B M. 2nd of 3.
11	" " 28	16 17 24	57 54 5	p F; p L; R; B * nr p. 3rd of 3.
12	1886 July 9	16 18 5	65 10 30	v F; v S; c E; 2 st. nr.
13	" " 6	16 18 32	56 15 3	e e e F; S; R; nearly bet. 5 p B st. in a curve n. and 3 F st. in a curve s.; e diff.
14	1886 June 28	16 23 16	55 37 18	e e F; p S; R; v diff.
15	1886 July 9	16 25 5	59 44 12	e e F; v S; R; in vacancy. Many p B st. s.; e diff.
16	" " 6	16 30 0	59 2 30	p F; p L; E; 2 st. nr. p.
17	1886 June 28	16 33 35	57 44 5	v F; v S; R; forms right angle triangle with 2 st. f.
18	1886 July 9	16 34 50	62 11 25	e e F; p S; * near f.
19	" " 3	16 45 1	4 49 29	e e e F; p S; R; bet. a distant B * f and a distant F * p.; e e diff.
20	1886 June 28	16 45 55	62 21 10	e e F; e S; e F * close; e diff.; sp. of 2.
21	" " 28	16 46 55	62 24 40	v F; v S; R; bet. 2 st.; nf. of 2.
22	" " 28	16 47 25	55 44 32	e F; S; R.
23	" " 28	16 50 50	60 43 8	e F; v S c R; a B * and a D * nr. p.
24	1886 June 9	17 1 55	60 32 21	e F; S; c E; F * nr.
25	1884 Aug. 1	17 25 20	58 35 10	v F; S; R; sp. of 2.
26	" " 1	17 25 30	58 36 55	v F; S; l E; * nr. nf. of 2.
27	1886 May 30	17 33 45	74 26 5	e e e F; p S; R; bet. 2 st. 4 F st. nr. p form arc of circle.
28	1886 June 9	17 43 55	67 38 4	e e F; S; R; p of 2; e e diff.
29	" " 9	17 44 30	67 38 4	e e F; S; R; f of 2; v diff.
30	1886 May 30	17 45 45	51 10 10	p B; S; e E; spindle. In field with Gamma Draconis.
31	1884 May 27	17 51 5	65 34 12	e e F; v S; R; bet. 2 pairs of coarse D st.
32	1886 May 30	17 53 0	60 49 30	e e F; p S; l E; e diff.; in vacancy. Only 1 v F * nr.
33	" " 28	17 53 30	62 39 20	e F; p S; v E. 1st of 3.
34	" " 28	17 53 50	62 40 20	e e F; v S; R; p B * nr. p, v diff. 2nd of 3.
35	" " 28	17 54 20	62 36 20	e F; p L; 2 B st. nr. f. 3rd of 3.
36	1884 July 24	17 54 44	50 45 15	v F; v S; R; 2 B st. nr.; in finder field with Gamma Draconis.
37	1886 May 30	17 56 35	73 25 31	e F; v S; l E; bet. 2 e F st.
38	1886 June 6	17 56 45	19 42 15	e e F; v S; R.
39	" " 28	17 56 45	64 18 42	e e F; p S; R; in center of a semi-circle of 4 st.
40	1886 May 27	17 59 45	66 35 25	e F; S; l E; H. 37 IV in field.
41	1884 July 23	18 22 0	66 33 26	e e e F; p S; R; forms triangle with 2 st.
42	1886 July 30	18 33 0	66 51 15	e e e F; p S; l E; lb M; e e diff.; 2 or 3 others in field.
43	1884 Oct. 25	18 33 30	67 0 55	e F; e S; bet. a v close * and a v F D *.
44	1884 Aug. 16	18 36 55	55 30 12	v F; p L; R; p B * nr. s.
45	1886 May 27	18 45 45	66 35 55	e e e F; p S; e e diff.; several B st. nr. n.
46	1883 Aug. 20	19 15 40	63 44 35	e e e F; p L; R; e e diff.
47	1886 June 5	20 35 55	65 40 25	p B; p S; R; mb M; p B * nr.
48	1886 July 12	21 36 46	12 3 31	e e F; S; R; p B * with distant companion close p; v diff.
49	1884 Nov. 9	23 11 45	28 23 40	v F; R; np. of 2.
50	" " 9	23 12 30	28 23 10	v F; p S; R; D * nr. sf. of 2.

The following nebulæ were discovered after the partial Catalogue No 4 was put in type, and are, therefore, arranged in the order of discovery instead of R. A.

No.	Date of Discovery.	α1885.0	δ 1885.0	Descriptions and Remarks.
		h m s		
1	1886 July 22	14 59 30	29°57′20″	e e e F; p s; l e; e e diff.
2	" " 22	17 26 4	57 37 11	e F; S; R; s p of 2; B * nr s.
3	" " 22	17 26 24	57 38 11	e F; S; R; nf of 2. This and the above point to the B * 8 magnitude.
4	" " 22	17 58 25	61 22 5	e F; S; c E. Course D * sp points to it.
5	" " 22	17 45 0	57 20 55	e e F; S; R. 1st of 2.
6	" " 22	17 45 0	57 21 10	e F; p S; R. 3st in a line nr and 3 others in a line point to it. 2nd of 2.
7	" " 31	18 30 55	67 3 53	p B; p S; v E.
8	" " 31	18 32 5	59 48 15	e e F; S, c E; bet a F and a p B *; nearer the former; e diff.
9	" Aug. 3	23 1 25	27 34 0	v F; S; R.
10	" " 3	16 38 52	66 15 25	e F; v S; R; forms a L equilateral △ with 2 p B st.
11	" " 5	16 54 25	63 25 16	e e e F; S; l E; l b M. Nearly in center of a L vacancy; e e diff.
12	" " 5	16 50 55	63 54 30	e F; p S; R; 4 or 5 st near sf in form of a curve.
13	" " 5	17 1 35	61 12 30	e F; p S; c E; sev. v F st close p.
14	1884 Aug. 15	17 20 30	62 16 15	e e e F; p L; i R; sev. e F st involved; B st nr sf.
15	" July 24	18 8 0	49 53 30	e e F; p S; R; in vacancy bet 6 st like sickle in Leo, and 4 like Alpha, Beta, Gamma, Delta Ursæ Majoris.
16	1886 Aug. 5	19 25 0	54 8 30	e F; p S; R; F * nr s.
17	1884 June 18	18 25 40	71 31 23	e e F; p S; l E; bet a near F *, and a distant B one.
18	" Nov. 9	23 15 15	25 16 18	e F; p S; R.
19	1886 Aug. 5	23 55 15	12 29 6	p F; p S; R; F * v nr. np. Nearly bet the 2 p of 3 st in line; np of 2. Neither place nor description agree with 5044.
20	" " 5	23 56 10	12 20 26	p F; p S; R; 2 F st nr in line with it. Not diff; sf of 2.
21	1883 Aug. 31	23 6 30	14 0 30	v F; S; R; bet 2 st.
22	1886 Aug. 8	23 4 35	10 24 24	e F; v S; R.
23	" " 8	23 14 45	26 41 13	p F; p S; c E; 3 st in a line near np.
24	" " 8	23 33 45	26 21 0	e e F; p S; R; p B * nr f; e diff; 6218 nr nf.
25	" " 9	23 46 28	10 50 10	e F; S; R; in center of equilateral △ of 3 st; D * nr np.
26	" " 9	0 28 30	−10 20 7	p F; p S; R; * nr nf.
27	" " 9	0 30 25	−10 45 20	e F; v S; R; v diff; only 1 * near.
28	" " 9	0 36 0	−10 38 48	v F; p S; R.
29	" " 18	17 17 10	60 44 5	v F; p S; e E; spindle, nearly bet 2 p B distant st; nearer the p *.
30	" " 31	21 20 40	13 41 12	e e e F; close sf of middle of 3 F st in a curve, middle * the brighter, e e e diff. Nebula nearly in same parallel as the s * of 4 in a row p.
31	" Sept. 1	17 23 45	58 55 33	e F; e S; R; e diff.; in center of equilateral △; np of 2.
32	" " 1	17 23 40	58 55 18	e e F; e S; R; e e diff.; sf of 2.
33	" " 1	17 26 55	58 56 33	e F; v S; R; nearly between 2 st.
34	" " 1	17 47 58	62 15 45	p F; p S; E; between 2 st and 3 st in form of a semi-circle.
35	" " 1	22 9 55	21 56 53	p F; S; R; mb M; 4 st in form of a square, near p
36	" " 1	22 16 30	− 4 41 18	v F; p L; R; 4 st nr sf point to it.
37	" " 1	22 26 30	11 7 24	e F; S; R; in center of 4 F st in form of a rhombus.
38	" " 1	23 18 40	13 20 36	e F; S; R; in vacancy.
39	" " 1	23 29 0	15 26 15	v F; v S; R; 2 st point to it.
40	" " 1	0 28 40	−11 23 25	p F; S; R.
41	" " 1	1 46 50	11 28 54	e F; S; R; B * nr f.
42	" " 1	2 30 5	11 8 56	v F; S; R; B M. forms trapezium with 3 st.
43	" " 1	3 12 50	− 2 23 24	v F; S; R; 4 st f in a row.
44	" " 2	22 38 0	8 6 0	v F; S; R; lb M.
45	" " 2	22 49 5	12 38 50	e e e F; S; R; e e e diff.; n of 2.
46	" " 2	22 49 5	12 36 20	e e F; p S; R; e diff.; 8 or 10 st in an irregular line p; s of 2.
47	" " 2	22 40 45	20 29 2	e F; v S; R; forms equilateral △ with 2 st., one the brighter.
48	" " 2	23 47 45	7 28 45	e e e F; p S; R; 5025-6-7 and 8 in field.
49	" " 2	1 9 30	− 2 13 33	p B; v S; l E.
50	" " 2	2 1 40	16 39 30	e F; v S; R; right angled with 2 st.
51	" " 3	19 46 10	59 37 0	e F; S; R; f of 2.
52	" " 3	19 45 25	59 37 0	e F; p S; R; p B * close s.; p of 2.
53	" " 6	19 59 55	65 55 0	p B; p S; R; B M.
54	" " 6	23 10 55	10 16 45	v F; v S; R; 3 st sf form a little right angle △.
55	" " 6	23 6 50	13 6 22	e e F; S; R; e diff.; 5 or 6 st nf in a line.
65	" " 6	3 2 20	3 39 44	p F; p S; R.
57	" " 6	2 30 47	20 35 53	p F; p S; c E; * near s.
58	" " 7	23 39 20	− 2 19 5	e F; p S; R; * nr s, which with one f and p forms a double △.
59	1885 Oct. 30	2 27 30	31 59 21	e e F; v E; p B * nr sp.

THE GREAT NEBULA IN MONOCEROS.

This interesting nebula is a *nova*, discovered some fifteen years ago, while comet seeking with the 4½ inch telescope. After satisfying myself that it was not a comet, it seemed probable that it might be simply a glow from the well-known cluster H 2, VII, to which it closely adjoins, but, finding the glow confined to one side only, I became convinced that it was a nebula, and being so bright and large, doubtless previously discovered. Obtaining Herschel's G. C., I found, by its absence from the list, that it was new. Two or three years ago, Mr. Barnard picked it up, mistaking it at first, as I had done, for a comet. On one very fine night, before the appearance of the red sunset phenomena, the 16 inch refractor showed it as elliptical with a center of condensation at each foci, as roughly represented in fig. 2, which was

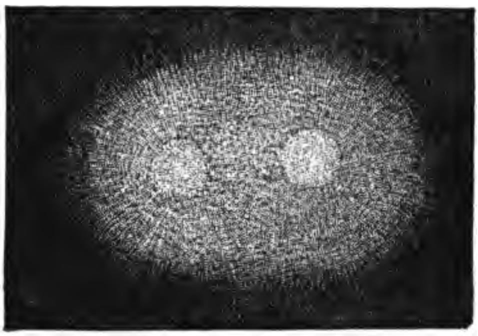


Fig. 2.

sketched for and published in the *Sidereal Messenger*. And though on no subsequent occasion have I been able to see it as illustrated, yet I have since observed another near, itself very large, with two or three contiguous outliers. The Monoceros *nova* is one of the largest nebulæ visible from this latitude. Its approximate position for 1886.0 is 6 h. 24 m. 45 s., Dec. + 5° 7′ 40″. It is somewhat brighter than the Merope nebula in the Pleiades.

THE SWAN OR HORSESHOE NEBULA

Proves to be a most wonderful object for study. It, however, bears scarcely the slightest resemblance to the pictorial representations as published by Lord Rosse, Trouvelot, Lassell or the Herschels. The accompanying wood

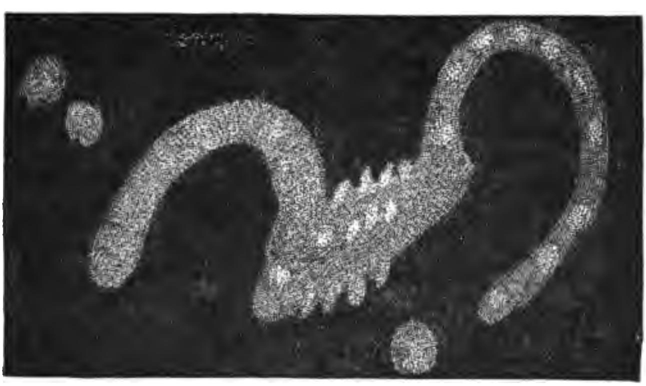


Fig. 3

cut, fig. 3, is, however, poorly illustrative of it, though it will serve to give the reader something of an idea of its extent and unique form.

This object is in the Milky Way, a region which, though rich in star-clusters, yields very few nebulæ. It is No. 4403 of General Catalogue and 17 of Messier's. Its approximate R. A. is 18 h. 14 m., Dec. — 16° 13′. The illustration, originally prepared for the *Sidereal Messenger*, for March, 1885, was sketched from memory and, of course, not to scale. The singular appendage at the following end has, as far as I know, never before been seen. It was first noticed on July 4, 1883. It was again seen the next evening, and, on July 6, was corroboratively observed by Messrs. Warner and Rebasz. Subsequently, on the occasions of their visits to this Observatory, after their attention had been directed to it, it was thus seen by both Dr. Copeland and Mr. Trouvelot. There is much of detail in it, and needs to be drawn to scale, by an expert, for adequate representation. I have not been able to trace the appendage to the pretty large, exceedingly faint nebula just preceding its termination, but have no doubt that, with a larger telescope, a coalescence would be detected. This latter isolated nebula is a new one.

SECONDARY TAIL TO PONS-BROOKS' COMET.

This comet presented many curious freaks, but its most interesting feature was a secondary tail of peculiar shape, seen only on the evening of December 29, first, by the writer, and after, by Mr. Streeter, an astronomical friend, who was visiting the Observatory.

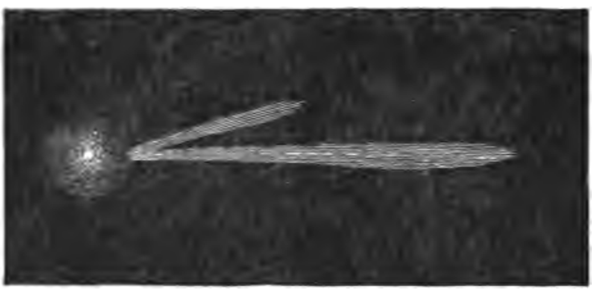


Fig. 4.

The cut, fig. 4, is an exact inverted delineation of its appearance at that time. The primary tail could be traced about 8°, and the secondary about 3°. The latter was an exceedingly difficult object to see. Both were perfectly straight.

Secondary tails are not always shortest, as, *e. g.*, on the evening of June 26, Comet II, 1881, exhibited, to the naked eye, a secondary tail extending to Pi Draconis, or some 55° or 60° long, which was seen by several visitors to my former Observatory. On the next evening, though the conditions for seeing were equally good, it had diminished more than one-half. This is the longest secondary tail extension I have ever seen recorded.

LEWIS SWIFT, Director.

WARNER OBSERVATORY,
Rochester, N. Y., U. S. A.,
January, 1887.

THE WARNER PRIZE ESSAYS.

In the Order in which tney were Awarded by the Judges.

THE WARNER COMET PRIZE ESSAY.

Comets: Their Composition, Purpose and Effect Upon the Earth.

By Professor Lewis Boss, Director of Dudley Observatory, Albany, N. Y.

In January, 1881, Mr. H. H. Warner, of Rochester, N. Y., Founder of the Warner Observatory, announced a prize of $200 in gold to any American or Canadian who, during the year, should discover a telescopic unexpected comet. When Comet "B," or the great comet, was discovered, effort was made to ascertain who first saw it, and had a conclusion been possible among the very many of claimants, a special prize would have been given. As none could be reached, Mr. Warner determined to give a special prize of $200 for the best essay on "Comets, their Composition, Purpose and Effect on the Earth." One hundred and twenty-five essays were sent in to Director Swift, of the Warner Observatory, and after a careful review, the Judges—Professor Elias Colbert, of Chicago, Ill.; Professor H. A. Newton, of Yale College, New Haven, Conn.; and Professor H. M. Parkhurst, of New York City,—unanimously awarded the prize to the essay signed "Hipparchus III," by Professor Lewis Boss, Director of the Dudley Observatory, of Albany, N. Y. Following is the full text:

Though modern science has taught us much concerning the physical nature of comets, no one has yet been able to construct a theory which is either complete or free from objection. With these facts in view, and so far as possible within our brief limits, and without the use of technical language, we will endeavor to outline some of the more important results of observation and reflection upon this subject. We shall be obliged to draw freely from the results elaborated during the last fifty years by Bessel, Winnecke, Bond, Newton, Zœllner, Bredichin and many others, without reference to individual authorities, or digressions upon rival theories and claims.

METEORS—OFFSPRING OF COMETS.

§ 1. About twenty years ago it was proved that certain annually recurring displays of meteors are due to swarms of small bodies, which revolve about the sun in elliptical paths, so situated in space as to encounter the earth at nearly the same time in each succeeding year. These paths or orbits were found to be identical in some cases with those of certain well known comets. The conclusion seemed irresistible and is now accepted, that shooting stars, or meteoroids, are simply the offspring of disintegrated comets.

Most likely, aerolites [large meteors] which sometimes reach the surface of the earth, are of the same origin. These bodies usually enter our atmosphere with velocities [relative to the earth] ranging from twenty to forty-five miles per second. In consequence of the inconceivable heat which

would be generated by such contact—manifested by the fiery train they leave behind—the smaller meteors, however dense, would be at once converted into impalpable vapor. Only the larger ones could survive the tremendous encounter, and reach the earth. Still other composed of more fusible substance, though very large, may be unable to either overcome the mechanical resistance of the air, or the transcendent heat produced. Furthermore, that fiery ordeal must strip aerolites of all volatile matter and leave only refractory substances behind Hence, analysis of meteoric stones might give us an idea of the real composition of comets which would be totally misleading; just as the ruins of a house, destroyed by fire, would be no index of the chemical composition of all the material it contained before the disaster.

TESTIMONY OF THE SPECTROSCOPE AND POLARISCOPE.

§ 2. The Spectroscope [light analyser] rather reluctantly yields some testimony as to the chemical and physical nature of comets. It seems to show that the nucleus is a solid or liquid incandescent [at a glowing temperature] mass. It proves quite conclusively that the matter surrounding the nucleus contains hydrogen and carbon in one of their numerous compounds. The flame of the Bunsen burner which contains one of the compounds, shows a spectrum [light analysis] which is very similar to, if not identical with, that observed in comets. Some observers have reported that these elements give evidence of their presence in the tails of comets at considerable distances from the head. If so, we must suppose the attenuated matter of the tail to be self-luminous. This may be attributed to some form of electrical action; since, considering the low temperature of space, it cannot be due to incandescence produced by ordinary heat.

Recent observations with the spectroscope seem to prove that a part of the light from comets is really reflected sunlight, since it faintly exhibits a spectrum like that of other bodies, which shine by reflected light alone.

The Polariscope [instrument for detecting reflected light] also gives evidence which leads to the same conclusion. The use of this instrument in examining faint sources of light is attended with great difficulties; and in the present connection, the records of different observers are not strictly harmonious.

RECORD OF THE TELESCOPE.

§ 3. Comets are seen in their simplest form as faint patches of nebulous light. They are usually circular or oval in outline, without remarkable difference of brightness from center to circumference. At a later stage of development the comet shows a diffuse brightness in its central parts, known as central condensation.

When a large comet approaches the sun, the structure becomes far more complex. The center condensation gathers intensity. Finally, a point or disc of light appears near its center, which shines with a light approximating that of the planets. This is called the nucleus.

NUCLEUS HAS NO DEFINITE MAGNITUDE.

Observers with powerful telescopes usually find that what we commonly call the nucleus has no definite magnitude. It continually measures less with increase of optical power. The inference is that the real nucleus, if it consists of a single solid body, must be very small, and much obscured by the vapors which surround it. Generally the nucleus appears to shrink in size as it approaches the sun. The most plausible explanation seems to be, that with lessened distance from the sun, the real nucleus gets hotter and brighter, and that, at the same time, the vapors near it become more transparent. Other explanations have been offered which we have no space to consider.

THE ENVELOPES.

We commonly find that the coma [nebulous matter about the nucleus] appears much brighter on the sunward side. In many cases, streams of matter appear to issue from the nucleus on that side. These assume a variety of forms, and are almost always curved backward, from the direction of the sun, at their extremities. Above the streams, or jets, are sometimes seen one or more arcs of light, concentric with the nucleus from which they appear to recede,—just as waves recede in widening circles from a stone dropped into still water. These envelopes, as they are called, are supposed to be hollow spherical segments of matter, more dense than the surrounding parts of the coma.

One highly important characteristic of the matter which surrounds the nucleus is well established. The rays of light from distant stars seen through it are not sensibly bent, or refracted. This shows that gases of an appreciable amount do not exist in comets.

THE PHENOMENA OF THE TAIL.

The strange appearance of the tail and the gigantic dimensions it sometimes attains, are well calculated to arrest the attention of mankind. It is not wonderful that the ancients should have regarded it with trembling apprehension, nor is it surprising that, even yet, it excites an absorbing curiosity among the educated, and the superstitious terrors of the ignorant. The matter of which it is composed must be expanded to an almost inconceivable degree; for even when it is millions of miles in diameter, the light of the faintest star is seen through it with scarcely diminished brightness.

THE BLACK STREAK IN THE TAIL.

Near the head, it often appears to consist of two streams of matter issuing from either side of the coma with a dark channel of separation between. The tail at this point generally appears to have the same diameter, from whatever direction in space it is viewed. We must, therefore, conclude that its interior is nearly or quite free from matter, and like a hollow cylinder or portion of a cone, as far as the dark channel extends. Beyond that point we may suppose that the interior fills up by gradual diffusion from the circumference. In some cases, and especially with small comets, the dark channel is wholly wanting, or but faintly indicated.

CURVED DIRECTION OF THE TAIL.

In order to give an idea of the situation of the tail in space, let us imagine a line from the sun continually prolonged through the moving head of a comet into space beyond. We shall always find the tail extending nearly opposite the sun, in the general direction of this prolongation, but curved more or less backward from it, in the direction from which the comet is moving. Sometimes we find more than one tail—each distinguished by the degree of its backward inclination. They have, indeed, been classified on this ground and found conformable to three general types.

ORIGIN OF COMETS.

§ 4. The facts thus far presented prove nothing as to the origin of comets. That question demands for its solution mathematical reasoning based on the calculated paths of all comets which have been observed. That discussion is beset with great difficulties, and as yet points to no absolutely certain conclusion. The balance of testimony seems to favor the supposition that comets originate outside the solar system. The planets move in nearly circular orbits about the sun; and no one has been able to show why comets, if they have the same origin, should move in elongated orbits, entirely differing from those of planets.

Let us suppose, however, that all comets must have taken their origin in some primeval nebula from which a solar system has been evolved. It has been shown that the velocity of a comet may be so much increased by the disturbing action of a large planet, that it may escape from the control of the sun, and be projected into the illimitable regions of space. Thus freed, it will go on in a nearly straight line forever; unless, perchance, some powerful source of attraction, like another sun, lying near its path, arrests its flight. The possibility of such an occurrence is by no means imaginary. At least one comet [Lexell's, 1770,] is supposed with good reason to have undergone that fate. There is every reason to believe that the same thing may have happened in other cases.

STELLAR COMETS.

All argument drawn from observation and reflection prove that the stars which surround us on all sides are remarkably like our own sun. Some of them are even larger and more powerful than he. Reasoning from analogy, we must suppose than these suns are also attended by comets. Hence, we are led to the conclusion that uncounted myriads of comets projected forth from millions of suns, during countless ages past, are now flying through space in every direction—restless messengers from star to star. By mere chance some of these bodies must come under the sun's far reaching power and be drawn into our planetary system.

PHYSICAL HISTORY OF COMETS.

§ 5. The mass [quanity of matter] of comets is conceded to be very small in comparison with that of the earth. How small it is, we cannot say. No comet has been found large enough to exert a sensible attraction upon any celestial body found in its vicinity. This fact confirms the conclusion derived from telescopic examination, that the real, solid nucleus, if it exists, must be extremely small.

It is certain that no body entirely gaseous could exist in space. The conditions for the stability of liquid bodies in their practical application to the explanation of cometary phenomena, are extremely complicated; since they are closely associated with the unknown elements—mass of the comet, solar radiation, and absolute temperature of space. It would also be extremely difficult to show how a swarm of small bodies could be preserved in a state of equilibrium, or resist the tremendous tidal action to which it would be subjected in the vicinity of the sun. In fact, we must view the conversion of a comet through some unusual catastrophe, into such a swarm, as the sure precursor of approaching dissolution. On the whole, it is probable that there is a solid or partly liquid body near the center of the comet. This body is more likely to consist of an aggregation of loosely cohering pieces or particles, than of a single, firmly-united mass.

Owing to the smallness of their attractive force, comets cannot retain a sensible atmosphere. This conclusion is confirmed by telescopic observation, as we have seen.

If, now, we suppose the nucleus to be approaching the sun, it will eventually reach a point where the liquid or other volatile matter on the "sunny" side commences to evaporate and be diffused about the comet. Without following the consequences of this evaporation into details, one can imagine for himself how the appearance of central condensation, of the streaming jets, and of the nucleus heavily obscured by vapors, might be produced.

To account for the backward curvature of the jets and the peculiar form and direction of the tail, we must look for some additional force. In all probability this force resides in the sun, and is directly opposite in its effects to the power of gravitation. But since the body of the comet obeys the law of gravitation with sufficient fidelity, we must find a repulsion which sensibly acts only on the molecules of gas or vapor.

The only force suggested by experience as competent to these requirements is that of electrical repulsion. Anyone can prove for himself that two bodies similarly electrified mutually repel each other. We know that the earth through effects of constant evaporation and other causes, is to some extent an electrified body. For the same reasons, we should expect comets to be electrified in a much higher degree. The sun itself certainly exerts an influence upon terrestrial magnetism. Violent commotions on its surface have occurred at the same time with unusual disturbances of the magnetic needle. Electrical repulsion acts in proportion to surfaces and not to volumes. On particles of matter in a state of infinitesimal subdivision it might act most powerfully, while not affecting a large body to an appreciable degree.

THEORY OF FORMATION OF TAILS.

If, then, we suppose the sun and comets to be sufficiently and similarly electrified, we have the force necessary to produce the backward curvature of the jets, and to drive off the smallest and probably outermost molecules of the coma to form the tail. Since, according to our hypothesis very little matter can be given off from the shaded side of the nucleus, we readily perceive why the tail should be hollow in appearance.

The orbit of the moving nucleus being curved, it is evident that the particles driven off at any time with less than infinite velocity, would continually fall more and more behind the prolongation of a line through the sun and comet—just as has been observed. If the matter contains molecules, varying considerably in size, the larger ones would be driven off with less velocity. These would curve backward more than would the lighter molecules driven off at the same time; and so we have the multiple tails which have been seen, as well as the classification already described. Elaborate examinations of their average observed direction and form suggest that each class may be composed of chemical elements peculiar to itself. We may even venture to suppose that the tail of greatest velocity and least inclination is composed of hydrogen. The second type may contain carbon, with or without other elements; and among those of the third, chlorine would most likely be found.

It is a common error to suppose that this hypothesis, as to the formation of the tail, requires a repulsive force of inconceivable power. The straightest tails which have been observed are accounted for by supposing a repulsive force not much greater than twelve times the sun's attractive power. The tail most frequently seen [scimeter-like in form] may be produced by a force about one-ninth of that amount, which is but little more than sufficient to overcome the attraction of gravitation.

It will be seen that it is equally erroneous to suppose any great amount of material wasted in the formation of the tail, when one reflects upon the transcendent lightness of its structure.

HOW COMETS AFFECT THE EARTH.

§ 6. The influence of comets upon the earth is in all probability quite insignificant. They may, like the sun, affect the earth's magnetic condition, and thus to some extent, possibly, its meteorology. No such effect has ever been perceived. In spite of some chance coincidents between the apparitions of great comets and remarkable public events, no well informed person now believes that there is any real connection between them. By a liberal and credulous interpretation of any frequently occurring celestial phenomenon, similar coincidences could be shown.

When a comet is converted into meteoric bodies, which impinge upon the earth's atmosphere, there is some direct, though probable, minute effect. Some have thought that a sensible portion of the heat which the earth

receives is generated in this way; but the weight of scientific opinion seems to be against that hypothesis. The impact of meteors upon our atmosphere must add some matter to it, and this is probably in the form of dust. This may be the origin of the so-called cosmic dust, which has been collected at sea in recent times. The finer particles of it may have some influence on cloud formations, and other meteorological phenomena; but all this is merely conjecture.

A more remote effect may be sought in the possible fall of meteors and comets upon the surface of the sun. Owing to his vast bulk, the sun would attract an immense number of these bodies; but it is quite certain that their effect upon the sun's heat is insignificant. It is now generally admitted that we must look for the origin of the sun's heat in a constant, though to us, imperceptible shrinkage of his vast bulk.

Some connection between the frequency of sun-spots and comets has been rather vaguely suspected. Were the search for comets systematically pursued with equal persistence for a long period, we might have some data for the formation of a sound opinion. Yet it would still be an open question, whether comets cause the spots, or whether greater activity of the sun tends in some way to render comets brighter, so that more will be visible—with probability in favor of the latter supposition.

Finally, it may be said, with all due respect to scientific decorum, that the appearance of a great comet does exert one most happy influence on the earth, in that it stimulates the curiosity of mankind, and directs their thoughts to the more particular contemplation of the glorious universe which surrounds them.

/

ON THE CAUSE OF THE
Remarkable Optical Atmospheric Effects
IN 1883 AND 1884.

BY PROF. K. I. KIESSLING, HAMBURG, GERMANY.

DURING the autumn of 1883, and for a considerable time afterwards, three remarkable optical phenomena strongly attracted the attention of all observers, not only by their extent over the whole of the torrid and both the temperate zones, but, also, by their long duration, namely:

First, an unusual coloring of the solar disc, which appeared in some places for weeks together, as if it were seen through green, or blue, or red glass;

Secondly, an uncommonly long and variegated glowing of the sky after sunset and before sunrise;

Thirdly, a singular ring around the sun, the cause of which has perhaps not yet entirely disappeared, since it was quite distinctly visible on some days in the summer of 1885.

The question as to the origin of these remarkable phenomena was for some time discussed by the whole civilized world, a connection between them and the enormous volcanic eruptions in the Straits of Sunda being from the beginning presumed to exist. The Royal Society in London intrusted a special committee with the investigation of this matter, but, for aught I know, its labors have not yet been brought to a close.

A satisfactory solution of the problem must fulfil two conditions. In the first place, it must show, by the aid of experiments, on what physical laws the phenomena in question are based; in the second place, it must explain by what occurrences that state of the atmosphere which is necessary for the production of those phenomena may have been brought about. For brevity's sake, I shall only speak of the appearance of the sky *after* sunset, for which the name of *after-glow* has come into pretty general use, but my remarks are, *mutatis, mutandis*, also applicable to its appearance *before* sunrise, the *fore-glow*, if I may venture to say so.

Before I attempt to answer the questions just mentioned, I must call the reader's attention to the fact that a perfectly developed after-glow is a comparatively complicated optical phenomenon, the particulars of which are not so generally known as one might suppose, considering the frequency of its occurrence. I think it necessary, therefore, to point out its characteristic peculiarities.

During a normally developed after-glow, there is, in the first place, always to be seen, above the setting sun, a bright whitish-yellow spot surrounded by a brownish circle. Then certain horizontal colored strata, arranged according to the refrangibility of the different rays of light, make their appearance not only in the Western sky, but also in the Eastern, opposite the setting sun; which latter phenomenon we may call the *counter-glow*. Finally, and this is not generally known, when the sun has descended four or five degrees below the horizon, there bursts forth, high above the horizontal colored strata, a red glare, which rapidly deepens in color, and at the same time expands upwards and downwards, so that, after a few minutes, a rose-colored segment of a circle of an altitude of nearly 40 degrees is seen resting on the lower strata, which, when the sky is perfectly clear and cloudless, soon assumes a most brilliant appearance, not unlike that of red-hot vapors, and then sinks down like a fine veil behind the horizontal colored strata. This red-glow, while quickly descending, and at the same time considerably expanding to the right and left, turns the yellow of the horizontal

strata into orange, their orange into vermilion. Sometimes, though comparatively seldom, after the primary glow has nearly vanished, a secondary glow appears, passing through the same stages as the first, but fading away much more rapidly.

The gorgeous glows of the years 1883 and 1884 exhibited all the characteristic peculiarities of ordinary glows, but surpassed these by the intensity as well as the variety of their tints. The spot seen above the setting sun, which is ordinarily whitish-yellow, was then frequently of a brilliant green or bluish silver color, nay, sometimes even vividly iridescent. The horizontal colored strata, too, though arranged, as usual, according to the refrangibility of the different rays of light, were then much more expanded and more intensely colored, sometimes overspreading the whole vault of the heavens. The counter-glow not unfrequently showed as deep hues as the after-glow itself. But what struck all observers most, was the red-glare, which, at that time, was of an unusually long duration and great extent, and of a peculiarly deep, lurid, fiery tint.

Now the question is according to what optical laws the phenomena here described may be produced by the presence of particles of foreign matter in the atmosphere. To enable myself to answer it, I have made a series of careful experiments with a view of ascertaining the optical effects of pulverized solid materials, smoke-like products of combustion, and artificially produced fogs. The result of my investigations may be briefly stated, thus: As the theory of diffraction, laid down by Frauenhofer, might lead us to presume, every particle of dust, smoke or fog causes, by itself, an inflection or diffraction of the light falling upon it. By *inflection* or *diffraction* we denote the deviation which rays of light undergo when coming into immediate contact with the margins or extremities of an opaque or translucent body. It has been found that a minute particle of matter produces, in this case, two different effects. In the first place, the light coming into contact with it is dispersed, and that the more, the smaller the particle is, or, what is the same, the nearer its extremities are to one another. In the second place, rays of the same color interfere with, or partially destroy each other, in such a way that, when, for example, red rays pass by a minute round particle of dust, its shadow exhibits a system of concentric dark and red circles alternating with one another. The rays of every other color, as *e. g.* orange, produce, by themselves, a similar effect; but the alternating dark and orange circles do not exactly coincide with the alternating dark and red circles produced by the red rays, and the same holds good with regard to the rays of the other prismatic colors, so that, when white light, consisting of rays of all the prismatic colors, comes into contact with the extremities of a minute round particle, a system of concentric rings is produced exhibiting all the colors of a rainbow.

These colored circles, when produced by a single particle of dust, are so faint that they can scarcely be perceived: but when light, as, for example, electric light, is made to pass through a dense group of many thousands of particles of exactly the same size, all the rings of the same color nearly coincide with one another, producing a most brilliant many colored image or spectrum, which we may easily make visible by causing it to fall upon a white screen. This effect may be most conveniently observed by strewing puff-ball spores or Lycopodium powder on a piece of plate glass, and looking through it at the flame of a petroleum lamp from which the shade has been removed. Other minute particles used in similar experiments may produce various effects. If they are of essentially different sizes, the rings of a certain color due to one particle do not coincide with the rings of the same color due to another particle, but all the prismatic colors mingle with one another, by which means, according to a well-known optical law, white light is again produced. A cloud of dust through which white light passes

may, therefore, be productive of a very intense coloration, or of a faint one, or of none at all, according as the particles of which it consists are exactly equal, or nearly so, or essentially different, in size.

Particularly interesting are the optical effects which are observed when light is transmitted through smoke-like clouds resulting from combustion or chemical union, and consisting of particles so minute that a single one of them cannot be perceived even with the aid of a microscope. When sufficient quantities of air containing hydrochloric acid, and of air containing ammonia, are made to pass into a large glass receiver, a dense bluish-white cloud of minute particles of sal-ammoniac is formed, through which the image of the sun, as reflected by a mirror, appears first bright reddish brown, then bluish violet, and at last bright azure, that is to say, it presents the same succession of colors which the sun presented on the 20th of May, 1883, as seen from the German corvette, "Elizabeth," during a rain of ashes. The same effects are observed when light passes through a receiver filled with phosphoric acid or with smoke of burned magnesium or of burned gunpowder.

If a receiver filled with such a nebulous mass is left standing quietly for some time, the larger particles sink down more rapidly than the smaller, thus forming broad horizontal strata of equally large particles. On transmitting, from one side and from a sufficiently great distance, diffuse daylight through these strata, they exhibit, from below upwards, the colors, reddish-brown, yellow, greenish-yellow, and pale blue, all of them very intense. But exactly the same colors are seen after sunset, if the sky is perfectly cloudless, and evidently owe their origin to a similar cause. The particles of vapor, dust and smoke, present in the air that rests on the Western horizon, are, of course, likewise arranged in horizontal stata according to their size and weight, so that the light proceeding from that part of the atmosphere below the horizon which is still illuminated by the sun, necessarily undergoes diffraction, in consequence of which the various prismatic colors make their appearance.

This phenomenon, however, cannot be produced unless there be fog in the air, and the formation of fog is again dependent on the presence of dust or gas. If air containing aqueous vapor is perfectly free from dust, no fog will appear in it, to whatever degree we may lower its temperature. But if it contains a quantity of extremely minute particles of dust or smoke and, at the same time, a sufficient quantity of aqueous vapor, fog is produced in it as soon as it is sufficiently rarefied or cooled. The optical effects of such a fog vary according as its particles are equal or different in size, or in other words, according as it is homogeneous or heterogenous. Only homogeneous fogs are capable of diffracting light in such a way that prismatic colors are to be seen. Such a fog may be artificially produced by cautiously introducing a few cubic millimetres of common air into a glass receiver containing pure filtered air and some aqueous vapor. The temperature of the receiver being now reduced, there appears in it, at once, an extremely fine, silver-colored fog of great transparency. On looking through it, as soon as it shows itself, at the reflected image of the sun or of the light of an electric lamp, it appears surrounded by two concentric rings, an inner one of a bright blue or green color, and an outer, far broader one, varying between a vivid purple and a most delicate pink. Intercepted by a white screen, the light issuing from the fog produces upon it concentric rings almost as intensely colored as the bands of colored light into which sunlight is broken up when passing through a triangular glass prism. At the moment of their first appearance, these colored rings exhibit a peculiar metallic luster. As the particles of the artificial fog in the receiver increase in size, the original colors of the rings are superseded by others, and these again by others, and so on, so that sometimes nearly all the prismatic colors are successively to

be seen. Artificial fogs of greater extent, which I produced in zinc cylinders five meters long and closed at both ends by plate glass, are capable of diffracting even sunlight that is made to pass through them directly, imparting to it a green or blue or violet coloration.

The optical effects of the artificial fogs which have just been described, enable us to trace the origin of the glowing of the sky before sunrise and after sunset, the physical basis of which has hitherto been a complete mystery.

It has already been shown that the horizontal strata appearing in the Western sky after sunset, are owing to the diffraction of the light that proceeds from that portion of the atmosphere which has already sunk beneath the horizon of the observer, but is still illuminated by the sun. The coloration of the sky above those strata is likewise produced by diffraction. This is proved by the observations of Prof. Krone, at Dresden, who, on looking at that portion of the sky through red glass, which entirely absorbed the yellow of the horizontal strata, distinctly saw that the red glare was a segment of a broad colored circle surrounding the sun. Mr. Pechuel Loesche came to a similar conclusion. During his stay in Damara, where the atmosphere is usually remarkably dry and pure, so that no horizontal colored strata can appear in it after sunset, he convinced himself by repeated observations, that the red light forms part of a circle, the center of which is the sun.

Within the limited space at our disposal, we cannot give a full and exhaustive explanation of every phase of a perfectly developed glow. We may, however, account for some of its most striking peculiarities.

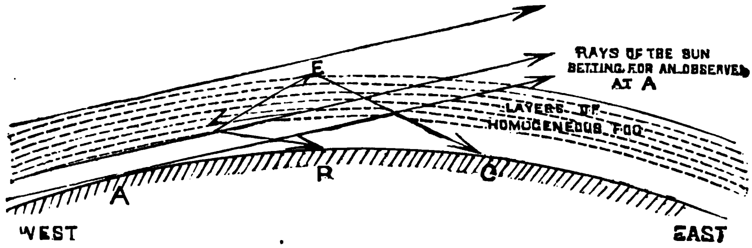
First of all we must bear in mind that any faint coloration of the sky remains invisible if, between the place where it is produced and the eye of the observer, there are strongly illuminated particles of fog, for these send forth so much diffuse light, that such a coloration is, as it were, overlaid and extinguished by it.

This is the reason why, as soon as the sun approaches the horizon, the red ring, which may have before been seen surrounding it, disappears almost entirely.

For the same reason the horizontal colored strata, giving forth a comparatively faint light as long as the sun is above the horizon, rapidly become more intense as soon as it has set.

Finally, the red light that may make its appearance as the last phase of a primary after-glow, cannot, for the reason assigned, attain to its full splendor before 20 or 30 minutes after sunset.

The strongest inflection of the rays of the sun, is brought about when they pass through a homogeneous fog in such a way as to strike the greatest possible number of its particles in succession. This will occur, for any given place, at the time when they are parallel to a layer of fog extending over it in a horizontal direction, that is to say, when the sun is there either rising or setting. Now, supposing the sun to be just setting for a certain place *A*, in the subjoined diagram, its rays inflected by the particles of fog about *Z*, the zenith of *A*, will produce a glow to the eastward of *A*, the counter-glow. At the place *B*, however, beneath the horizon of which the sun has already descended so far that the lower strata of air over it are no longer illuminated by diffuse light, and this is the case some 20 or 30 minutes after sunset, a red glare will be seen to the westward in the direction of the line *BZ* and at a certain elevation above the horizon. Provided the conditions on which the diffraction of light depends be particularly favorable, the whole vault of the heavens from *Z* to *E* may, to an observer at *B*, appear bathed in a flood of red light.



Perpendicular Section of the surface of the earth and of layers of homogeneous fog at a great elevation above it.

The secondary glow, which shows itself more rarely and only when the colors of the primary glow have been very intense, does not admit of so simple an explanation. I have collected all the instances of uncommonly intense glows observed from 1879 till 1881 in Switzerland, and recorded in the annals of the Central Meteorological Institution of that country, and I have also investigated and compared the densities and temperatures of the air that were observed during each glow at certain Swiss meteorological stations situated at different heights above the level of the sea. In this manner I have ascertained the fact that, whenever an intense glow before sunrise or after sunset was seen in Switzerland, the temperatures observed at the high-situated meteorological stations of Hohenpeissenberg and Puy de Dome were higher than the temperature observed at less elevated places situated in the vicinity of those stations; which state of the atmosphere, according to Professor Hann's investigations, is always found to exist when a barometrical maximum is observed. From this we may conclude that red glows of an unusual intensity are caused by extensive layers of homogeneous fog produced in those higher strata of warm air which come into contact with the colder air below them, and the temperature of which is consequently lowered so much that the aqueous vapor contained in it is condensed. Now, such layers of fog seem also to be capable of reflecting glows, so that for example an after-glow seen by an observer at a place *B*, in the direction of the line *BZ*, may produce to an observer at *C*, a place to the east of *B*, a secondary after-glow to be seen in the direction of the line *CE*.

From the 28th of November to the 2nd of December, 1883, a broad stratum of warm air, extending to a great height above the surface of the earth, lay over the whole of Europe from the Pic du Midi in the Pyrenees and Dovre in Norway, to Vladikawkas in the Caucasus and Slatoust on the western slope of the Ural. At the same time, according to the unanimous testimony of all attentive observers, a layer of fine fog was seen high up in the air, often enfeebling the light of the sun and imparting to it an unusual hue, while, after sunset, the most splendid displays of horizontal colored strata and red glares were frequently witnessed throughout Europe. Besides, it is proved by numerous observations that this fog, which must be considered as the principal cause of the unusual optical effects to be seen in the skies in 1883 and 1884, showed itself also in other parts of the temperate zones as well as within the tropics.

But what caused this extraordinary fog? That is the question which we must now try to answer. It seems that there are but two possible ways to account for it. The dust (or gas) necessary for its formation must be derived either from a terrestrial or from a cosmic source. As it was from the first presumed that it might be due to the volcanic eruption in the Sunda Strait, I have consulted a great number of periodicals as well as the journals of many sea captains, and have entered on a map of the world, all the days on which extraordinary colorations of the sky and the sun were seen in 1883 and 1884. On a careful examination of this map, it will become

perfectly evident to every one that those remarkable optical phenomena proceeded from the Sunda Strait, followed the direction of the monsoons and the trade winds, and finally diverged from the tropics towards the poles. All doubts in respect to the origin of the foreign matter present in the air in those years and necessary for the formation of extensive fogs at a great height above the surface of the earth, must therefore be dismissed. We are compelled to say that it issued from the craters in the Sunda Strait.

The way which it took is easily traced. In the first place, we may safely suppose that a considerable quantity of water found its way down to the seat of the volcanic forces, and, being suddenly transformed into steam of great tension, caused a tremendous explosion, by which an enormous quantity of gases and smoke-like dust was thrown to a great height; whence it was carried still farther upwards by the powerful current of ascending hot air which usually prevails in the tropics. As this matter had of course originally the rotatory velocity of the volcano from which it issued, and was besides passing through layers of air moving rapidly from east to west, it could not fail to fall back at a constantly increasing rate, finally perhaps at the rate of 80 nautical miles an hour, thus completing nearly three revolutions around the earth, from east to west, in the course of thirty days. Now, this agrees perfectly with the observations made with regard to the re-appearance of the extraordinary optical phenomena in question at certain places. That the volcanic matter in the atmosphere gradually diverged from the equatorial regions towards the poles is, of course, due to the fact that the air ascending in these regions, after arriving at a sufficient height, is gradually cooled, and then descends again towards the poles.

The volcanic eruptions which occurred in Alaska in 1883 and 1884 may likewise have contributed to produce the remarkable appearances which the sky and the sun then frequently presented. But the question cannot be answered decisively before sufficient returns have reached us from Central Asia.

Together with the glows and the unusual colorations of the sun, another optical phenomenon, less striking, but no less remarkable, attracted in 1883 and 1884, the attention of meteorologists, namely: a peculiar reddish ring surrounding the sun at some distance, and visible not only when the sky was perfectly clear, but also through gaps between the clouds when it was partly overcast. This phenomenon was named by Professor Forel "Bishop's Ring" in honor of Mr. Bishop, at Honolulu, who first saw it on the 5th of September, 1883. Wishing to ascertain in how large a part of the world Bishop's Ring had shown itself, I sent in November, 1884, a circular to the principal meteorological stations in every country, begging to be informed where and when it had been seen. The numerous answers which I received I entered on a map, from which it appears that, within the tropics as well as the temperate zones, it was first seen at the same time when the extraordinary glows made their appearance. Afterwards, especially in the summer of 1884, it was sometimes so intense that even sea captains, who generally take little notice of optical phenomena, made entries in respect to it in their journals. From the beginning of the year 1885, however, Bishop's Ring began to fade away, and at present (October, 1885,) it is no longer visible, either in Europe or America.

The boundaries within which this phenomenon was observed, its gradual disappearance, and the comparatively short time (20 months) during which it was visible, seem to me to show that it was produced by extremely fine particles of foreign matter floating in very high portions of the atmosphere. Thus Bishop's Ring furnishes, in my opinion, another argument in favor of the theory that the extraordinary optical phenomena presented by the sky and the sun during the years 1883 and 1884, were produced by volcanic eruptions.

These years, therefore, may be looked upon as a turning-point in the history of the science of meteorology. For, although similar phenomena had repeatedly been witnessed after volcanic eruptions, as for example, in 44 B. C. throughout central Italy after an eruption of Mount Vesuvius; in 1721 from Persia to France after the terrible earthquake which destroyed the town of Tabriz; in 1783 throughout Europe after an eruption of Skaptar-Jökull, and, finally, in 1831 throughout southern Europe after the eruption of Ferdinandea:—yet it was the eruption in the island of Krakatoa that first called forth scientific investigations which seem to show, conclusively, in what manner those phenomena are effected by volcanic eruptions.

[Prof. Kiessling begs to state that this essay was originally written by him in German, and that the present English translation was made by Dr. G. H. Haring, Hamburg, to whom he herewith retnrns his best thanks.]

THE RECENT SKY-GLOWS.

BY JAMES EDMUND CLARK, YORK, ENGLAND.

ALTHOUGH the recent remarkable glows are abnormal, nevertheless every phase, except the counter-bow, has been noted under ordinary conditions by competent observers.* In this way most of the phenomena have been explained and Prof. Kiessling, of Hamburg, has reproduced, very simply, nearly all the effects.†

The following notes aim:—

1. To give a clear and succinct account of the phenomena themselves and their sequences, based altogether, after November 24th, upon personal observations.

2. To elucidate obscure points and less certain interpretations.

3. To sketch the connection with Krakatoa.

A brief paragraph in *Nature* (June 7th, 1883,) announced that Mount Karang, on Krakatoa, in the Straits of Sunda, was in violent eruption. The date, learnt later with other details, was May 20th.

On August 26th began an eruption, perhaps the most tremendous known. In *Nature*, September 27th, Mr. O'Reilly suggested careful watch for "any abnormal conditions of atmosphere" * * * "during the coming months" from the immense volume of gases ejected.

From October 11th reports poured in of "Blue" or "Green" Suns in India, first noticed September 8th at Madras (*Nature*). On the 13th, upon "a smoky haze of singular appearance" occurred, perhaps, the first reported glow and after-glow. Mr. Manley (*Nature*, XXVIII, p. 576,) suggested a connection with the Java outbreak. "Blue Suns" were also reported all around the Equator, notably, at Trinidad, September 2d, and Honolulu, September 5th.

On November 9th (*Nature*, XXIX, p. 55,) Mr. Russell observed the glows in Surrey, his letter recording seven points of special interest. Similar effects on the same and following evenings were widely reported over *Southern* England.

November 24th, the writer believes, was the earliest record for *Northern* England. A letter to me, dated December 4th, besides recording the main features, including "Bishop's Ring," suggests a connection with the Indian observations, and, therefore, with Krakatoa, pointing out the immense height to which the "impalpable" dust must have ascended and its importance as affording nuclei for vapor condensation.

This, perhaps, was the earliest published suggestion (preceding those of Mr. Symons and Mr. Lockyer) of a connection between the English phenomena and Krakatoa, and the earliest European record of "Bishop's Ring."

**As Von Bezold, of Munich, and Dr. Hellmann; See Kiessling's "Dæmmerungserscheinungen im Jahre* 1883," *p.* 8. † *Idem, pp.* 43-53.

Similar appearances became rapidly common over both Temperate Zones, and have re-appeared at intervals ever since.

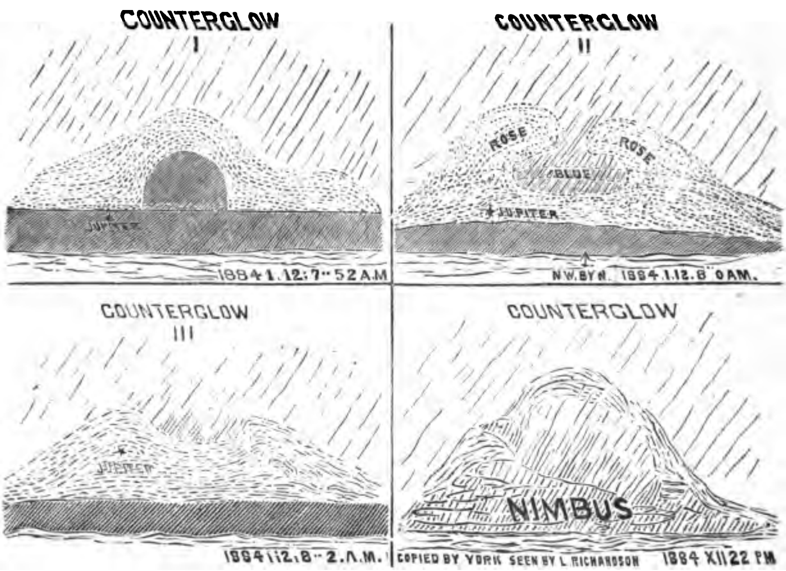
The writer's observations at York, (occasionally at Street, Somerset,) represent 16 "periods." The main points are summarized in the table on opposite page.

Selecting for comparison the maximum of the 67 sunset glows, the waxing and waning is very notable, minima coming at the 4th, 8th, 13th and 15th periods. Curiously, an increase occurs on each anniversary of the Krakatoa eruption.

The morning and evening effects were obviously alike; yet meteorological changes often modified their development. Regarding, then, sunrise as simply sunset reversed, the following sunmarizes the writer's personal observations:

A "glory" surrounded the sun. At first it was, for 10°, "yellow," or "tawny" and the next 15° to 30° "rose or salmon-colored, gradually changing to ordinary tints; the clouds grey-green in contrast." After 1883 the inner part assumed an exquisite silvery, sheeny look, or was entirely absent, the rose approaching nearer the sun, if that were under a cloud. On approaching the horizon the glow grew "tawny" or "muddy."

About 10 minutes after sunset, the opposite sky became tinged with dusky rose, —the *Counterglow* culminating at 25 minutes to 30 minutes, in a *Counterbow*, almost semi-circular, resting upon the Counterglow, thus separated from the Earth shadow, which was often very obscure.* The dark centre, 10° radius, showed the sky-tints above the counterglow. The rose reached 10° to 14° further occasionally being rayed, as on December 22, 1883, when one streamer nearly reached the zenith; and on September 13, 1884, when the bow itself was ill-defined. In its inception the counterbow resembles a gigantesque railway chair.



* *See figs.* 1-4.

SUMMARY OF SUN GLOWS.

EXPLANATIONS:

—*Foreglow* *C—Counterglow.* *beginning.*

G—Glow. *A—Afterglow.* *m—maximum.*

Gb and Gc refer to the rose tints. *e—ending.*

Figures give min's before sunrise, or after sunset.

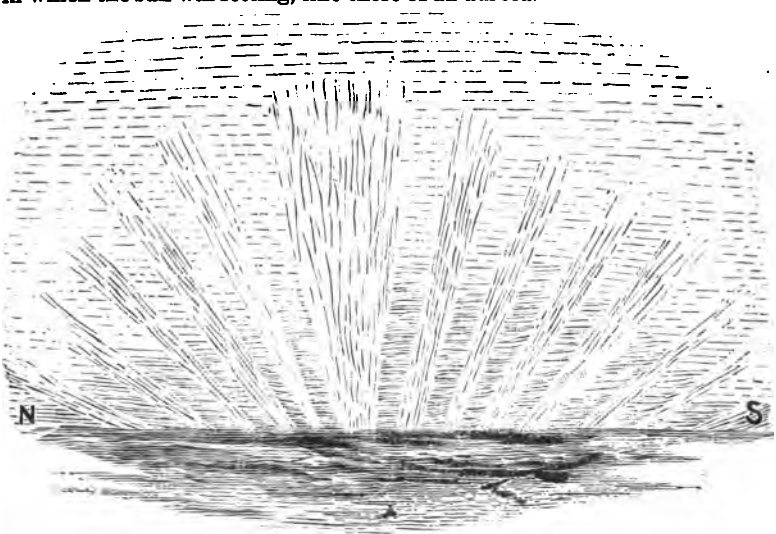
PERIODS	NO. OF DAYS.	Fb.	Fm.	Fe.	Gb.	Gm.	Ge.	Cb.	Cm.	Ce.	Cb.	Cm.	Ce.	Gb.	Gm.	Ge.	Ab.	Af.	Ae.	LOCALITY.
1883 XI 25 to XII 4	6		111	87	52	37								(64)	61½	82		91	137	York.
1883 XII 16-25	3													36	43	54	56	74	184	"
1884 I 6 to I 3	12		84	56	49	40	26	31	29	21	19	28	35	27	36	45	65	74	109	"
1884 II 10-24	6		63	50	40	34	24		24	19	19	26	38	25	35	47				"
III 1-20	3				43	34	29							15	22	30				"
IV 9-25	9				35	26	20	22	15	7				19	25	36	42	49	58	"
V 24-25	2													32	39	47				"
VI 12-VII 2	3													25	34	48				"
VIII 4-24	3													12	24	(23)				"
IX 5-X 18	13				43	32	23		25	10	18	19	23	28	37	48				"
XI 20-26	3													30	38	50				"
XII 21	1													22	25	35				"
1885 III 6-20	4													20	28	30				Street.
VI 26-30	5														21	(22)				York.
IX 19	1													25	35	40				Street.
X 7-XI 6	10	82	52	46	42	33	29				6			22	31	42	52	57	82	York.
TOTAL 15	84																			"
Maxima																				"
Minima																				"
SPECIAL DATES.																				
1883 XI	28		120												38			78		York
	29		102	87	52	37								64	79				139	"
XII	25														44	60	61	79	129	"
884 I	11													17	39	77		87	122	"
	12		96	64	56	44	21		34	21	18	28	35		42	56	60	65	125	"
IX	12										18	19	23	28	33	42			67	"
	13				45	34	25		25	10				25½	33	43	46	50	60	"
	14				41	31	21		26											"
1885 IX	19													25	35	40				"

About 30 minutes after sunset, the counterbow rapidly vanished, usually soon followed by the counterglow. At the culminating moment, however, traces of rose began to appear above the point of sunset. Some time before sunset the rose of "Bishop's Ring," disappeared, leaving the "glory" to form a cone of brilliant, silvery light, enclosed bv sunset greens, shading into the ordinary twilight-indigo.

The main *glow* began by the summit of this cone becoming suffused with delicate rose tints. These extended rapidly, especially upwards, there merging into violet, and, the zenith being reached, "imperial purples." The sky beyond assumed the richest indigo shades; whilst Venus and the moon assumed exquisite complementary blue-greens.

A very important accompaniment, especially of the richest displays, was the appearance, just before sunset, of the filmiest of clouds. "To me the glare never seemed as if reflected from cirri; it was much more like that from the smoke-originated clouds of manufacturing districts." They often showed faintly-marked striæ, frequently running from S. S. E. to N. N. W. The glow was "blotchy" when most intense, thus indicating their presence.

Sometimes, especially in September, 1884, and in midsummer, 1885, dark bands divided the glow, often cutting it off abruptly, especially on the north side.* So early as November 26th, at Street, Somerset, the writer's father observed "rays of the pink light shooting up from behind the cloud in which the sun was setting, like those of an aurora."

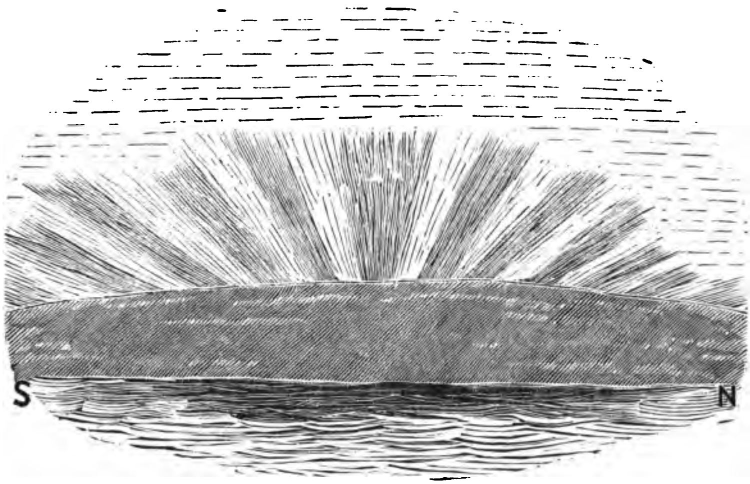


(Repeated at Sunset.) SUNRISE-GLOW, 1884 IX 13th.

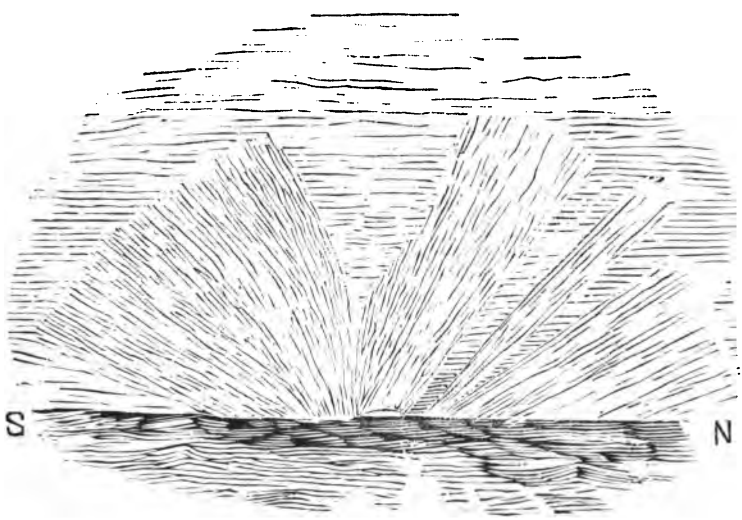
While thus developing upwards, an exquisite green spread out below. This seemed to extend slightly upwards, quickly followed by yellows along the horizon and these by orange, the green disappearing as the rose sank into them; finally little but a lurid glow remained.

But soon, though generally more than an hour from sunset, the *afterglow* occupied the position vacated by the glow, being much ruddier in tint. The brightest, coming about an hour and a half after sunset, resembled the glare from a tremendous conflagration below the horizon, and deceived experienced firemen. Whilst small print could be read, faint stars, as the Pleiades and Pons-Brooks comet, were visible through it. This reached a maximum in a very few minutes, and soon passed away, leaving a lurid,

*See *Illustrations.*



From Notes.) COUNTERGLOW, A. M., 1884, IX 13.



SUNSET-GLOW (Street, Som.) 1885, VI 27.

fiery glare along the horizon, lasting even two hours and fifteen minutes from sunset.

Let us, next, briefly state and apply the explanations so excellently developed by Professor Kiessling.* He divides the normal sunset thus:

Prelude: Silvery glistening of the western horizon.

First Act: Sun enters this; sets; cone of light reaches up about 20°.

Second Act: Tinges on clouds, first opposite sun; blue to reddish-violet tinge on sky. Earth-shadow appears, surmounted by ruddy counterglow, which, 20 to 25 minutes from sunset, suddenly disappears; clouds to west brightly tinged.

Third Act: Apex of cone glowing, shading off on all sides most gently, slowly sinking to mingle with yellow along horizon; these to orange; then lurid

Occasional Epilogue: Very faint re-illumination.

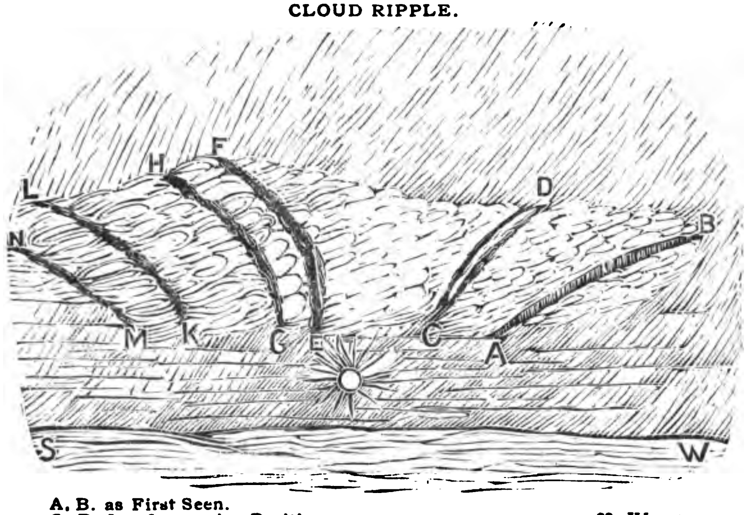
The whole he ascribes (p. 31) to diffraction through a very lofty stratum parallel to the Earth's surface, consisting of very uniform haze particles.

Such a haze always accompanies a well-developed sunset. But the effect is neutralized unless the inferior layer is unusually transparent. Else it contains particles so greatly varying as to dissipate the diffracted rays.

Such a layer will result from warm, moist air,† the presence of which, accompanied by (except the last) brilliant ordinary sunsets, is shown by the table on the opposite page, condensed by the writer from Kiessling's extensive series in "Das Wetter" II, 9. The last one refers to the first German observations of sunset phenomena. Hohenpeissenberg is 35 miles S. W. from Munich, both probably below the sky-region producing sunrise effects at Santis. The loftier stations accentuate the difference. Normally Munich should average 2½° warmer than Hohenpeissenberg.

The following confirms independently the existence of such marked lines of contact. On December 25, 1883, the writer observed, at 2:45 P. M., a "ripple" of clear sky, ¼° to ¾° broad, traversing a beautifully marked, lofty cirrus above the sun, traveling 90° in 10 minutes, ending 40° to 50° long. The cloud, as this passed along, melted entirely, except in its densest portions, which turned from opaque dark to transparent white. Evidently the crest of a lofty, warm wave penetrated right through the cirrus cloud, which was fringed with exquisite diffraction bands.

CLOUD RIPPLE.



A. B. as First Seen.
C. D. &c. Successive Positions. 1883 XII 23.

*"Die Dämmerungserscheinungen," also "Das Wetter," passim, especially I 1 and II 9.
† See table, opposite page.

SUNSETS OBSERVED AT SÄNTIS (8200′), N. E. SWITZERLAND.

DIFFERENCES OF TEMPERATURE,

At HOHENPEISSENBERG, (altitude 3,300 feet, [994 metres]) compared with MUNICH, (altitude 1750 feet, [528].)

DATE OF SUNSET, other stations than Hohenpeissenberg.	Upper line gives date; lower, difference of temperature in °C.						
1883, January 30th, - - -	28th,	29th,	30th,	31st,			
	—3·6	+2 7	***+4·3***	—2·6			
" February 11th, - -	10th,	***11th,***	12th,	13th,	14th,		
	—2·0	+8·2	+0·1	+6·1	+0·7		
" April 27th, 28th, - -	25th,	26th,	***27th,***	***28th,***	29th,		
(Slight).	—4·9	—2·1	+1·2	+2·9	+0·7		
May 5th, 1883, - - - -	3rd,	4th,	***5th,***	6th,	7th,		
	—3·4	—1·7	—4·5	—4·1	—2·5		
But on Rigi, 5950′, - - -	—10·4	—8·8	—7·7	—8·5	—8·6		
Säntis, 8200′, - -	—14·1	—13·4	—13·1	—11·3	—12·1		
St. Bernhard, - -	—14·7	—14·4	—13·6	—13·6	—11·4		
1883, September 20th, - -	18th,	19th,	***20th,***	21st,	22d,		
	—3·8	—0·9	+5·5	—2·0	—0·2		
Rigi, - - - - -	—7·6	—5·7	+1·2	—6·5	—7·0		
" Oct. 9th and 11th, -	7th,	8th,	***9th,***	10th,	***11th,***	12th,	13th,
	—1·9	+1·4	+0·3	+1·7	+6·5	+2·0	—1·5
" Nov. 22d and 23d, -	21st,	***22d,***	***23d,***	24th,			
	+0·6	+1 6	+4·4	—2·5			
" Nov. 29th and 30th, -	27th,	28th,	***29th,***	***30th,***	Dec. 1,	2d,	
	+0·8	—2 6	—1·6	+2·6	+5 2	—2·4	
Säntis, - - - - -	—7·5	—9·9	—4 2	+2 3	—0·7	—9·7	

The writer has not yet been able to obtain stations to associate with York in making comparisons similar to Kiessling's tables. Perhaps Fort William and the summit of Ben Nevis would be most satisfactory. A careful examination of local meteorological conditions indicates the absence of any prominent co-variation; but some minor agreements are exhibited in the table on opposite page.

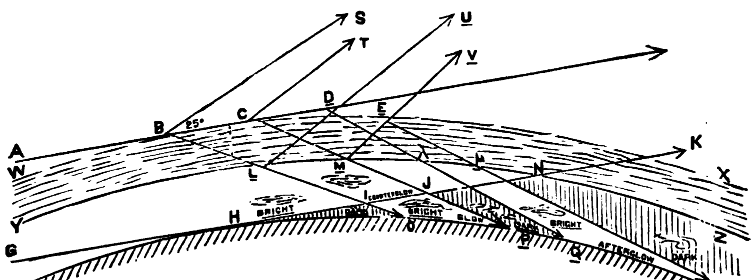
Professor Kiessling finds experimentally that the greatest deviation for red rays from a fine haze layer, forms a cone with an angle of 25° to 30° to the sun's rays, (*as angle S B C in diagram below.*) The chief effect may therefore be expected at this angle. Within it the rays, he says, meet with particles so varying as to re-combine the diffraction colors. But is it not rather due to the rays striking the haze at such varying angles? For, at the given distance, they fall tangentially over a vast area of identical particles, thus causing similar diffraction.

The disappearance of "Bishop's Ring" as the sun approaches the horizon, shows how easily the glow becomes obscured. This is partly due to absorption, but chiefly to the same irregular diffraction which turns the day-glow tawny along the horizon, as seen at York. Only as the direct rays of the sun leave these lower, larger, unequal particles can the sunset glow be seen. The rose or violet tints never appeared within 5° of the horizon, where the silvery green changed only to yellow, orange, and lurid red. The "imperial purple" appeared only high up, usually at or beyond the zenith.

The *rays* were doubtless due to clouds, as a rule below the horizon, intercepting the original rays. But dark bars were recorded from visible clouds in November, 1883.* In October, 1885, such a bar was observed shifting its position.

The *Counterglow* is due to reflection from the very mist particles which obscure the glow itself. The diffracted rays, striking such particles at or near the line of the Earth-shadow, are reflected along their return course among unilluminated particles, thus suffering less obscuration, the more so that these lower layers have, of course, a much greater number of particles.†

BASED UPON KIESSLING'S "DÄMMERUNGSERSCHEINUNGEN," p. 32.



EXPLANATION.

H R Surface of Earth.

G H K Ray tangential to ⊕ at H.

B L, C M diffracted rays, striking the lower haze-surface, Y Z, at L & M; G K at I & J; ⊕ at O & P.

L D, M F, the same rays reflected, part passing off along D U, E V.

Q R Seat of afterglow.

W X Y Z Haze cloud I to ⊕.

A B C F Parallel ray, tangential to upper haze-surface.

I J seat of counterglow to persons E of O.

O P Seat of glow, cirri relit.

D λ, E μ, 2nd internal reflection of L D, M E, striking ⊕ at Q & R. Clouds lit up 3rd time, (as Sept 12th, 1884).

M R causes the *very* prolonged *red glare* along horizon.

LETTERS UNDERLINED INDICATE ADDITIONS.

* *Vide supra, p. 4.* † *See explanatory diagram, above; also, as rays nearer I than J are reflected at a relatively higher angle, these, being nearer the earth, are also more obscured; compare close of paragraph.*

METEOROLOGICAL COMPARISON.

Observations classed as: (1), Faint; (2), Fair; (3), Fine. Morning and Evening Glows distinct.

CHARACTER OF OBSERVATIONS.	TOTALS.	BAROMETER.						MEAN THERMOMETER.				RAINFALL			RAINBAND.		
		Rising.	Steady.	Falling.	Over 30·2′.	30.2—29·5.	Under 29 5.	Rising.	Steady.	Falling.	Abnormal (+).	None.	Slight (under .05).	Strong (over .05″).	None.	Slight ("1").	Strong (2–5).
Strength (1).	37	9	16	10	6	25	4	8	16	11	2	20	9	4	8	14	3
" (2).	55	23	15	17	12	36	7	8	29	18	4	28	11	9	15	11	9
" (3).	23	10	6	7	12	8	3	5	13	5	3	11	3	7	8	4	3
Total (1) + (2) + (3)	115	42	37	34	30	69	14	21	58	34	9	59	23	20	31	29	15
" (2) + (3) only.	78	33	21	24	24	44	10	13	42	23	7	39	14	16	23	15	12
Result giving value to (2) double of (1), and to (3) treble that of (1).	216	85	64	65	66	121	27	39	103	62	19	109	40	43	62 Mean Rainband 0·9.	48	30

CONCLUSIONS:—Tendencies towards: (1) High and Rising Barometer.
(2) ∴ Falling Temperature, yet above average at the various periods.
(3) Dry days (largely accounted for by more chance of clear sky).
(4) Slight Rainband; average probably 1·2 to 1·9.

The COUNTERBOW, the writer believes, no one has yet explained. Is the light from the region of maximum diffraction so concentrated that, on haze particles just above the Earth-shadow, a *fogbow* results? This would be cut off sharp by the Earth-shadow; meanwhile the wider-scattered glow would be reflected as a long, narrow band separating the bow from the Earth-shadow. A feeble glow is *preceded only* by the counterglow. Again, the top of the bow comes last after sunset, because its rays, after the internal reflection and refraction, are more absorbed than those at the base of the bow, because they have to traverse a greater thickness of illuminated haze.

On December 22, 1883,* and September 13, 1884, (A. M.) the counterbow and counterglow, respectively, were observed rayed obscurely, the latter time with 9 bars, against 19 noted 5 minutes earlier in the glow, but broader. No doubt only the higher, central parts were seen reflected.

Finally the *Foreglow* and *Afterglow* Prof. Kiessling ascribes to simple reflection of the sunlight essential for the principal glow. For this the lofty diffracting cloud-haze requires a mirror-like surface. Such he proves experimentally possible, but without explaining the manner in which it acts. Possibly the rays are *internally reflected* at the lower surface and again at the upper, part emerging after this second reflection at nearly the same general angle and therefore the same center of brightness. As the diagram indicates, however, the same curvature which brings the afterglow so quickly after the glow, brings its centre rather higher. The diagram also shows how, with a thin haze-cloud, the two may coalesce. The more brilliant the glow the later, always, was the maximum, as well as first appearance of the Afterglow.

Assuming the time of maximum to come when the solar rays strike the upper surface of the cloud-haze tangentially, then, whatever the height of the under surface, say 15 or 25 miles, the height of the upper surface must be measured by the time of maximum glow. Hence the brightest glows were also the latest, coming as much as 80 minutes after sunset, (December 1, 1883,) whereas faint glows were only 20 minutes, (March 1, 1884,) (October 7, 1885,) and once only 10 minutes (June 29-30, 1885,) from sunset. Of the fewer recorded morning glows, the latest was 44 minutes, (January 12, 1884,) the least, 23 minutes, (April 13, 1884,) the evening interval next day being also 23 minutes.

Faint glows begin, also, much earlier, because intensity will vary as thickness and the lower parts of a thick haze, tending to consist of larger particles, would neutralize the earlier glow on the upper parts. With a thin haze-cloud these layers become themselves the diffracting strata.

An interesting transition from the ordinary diffracted effect on cirri, to that of the glows, occurred in December, 1884. On the 11th, at York, two small clouds were affected; on the 13th it appeared as a fringe to a long, dark, very lofty haze-cloud averaging 18° above the S. S. W. to N. W., the colors occasionally thrice repeated. Above this, the haze was translucent with a second similar fringe. Thirty-five minutes after sunset, the dark cloud became violet, the translucent, steel-blue, both finally melting away, but reappearing later, the translucent band of a strong twilight white. This cloud was also observed widely over N. W. Europe.

Telescopic definition has of late been unusually poor, a strong argument for the constant presence of the haze-cloud, though so often non-apparent. If the basis is volcanic dust, then the opacity may vary greatly, as much or little moisture condenses around the particles. The relative humidity, also, may have been appreciably increased by the vast volumes of steam shot into these lofty regions.

Accepting that the color effects spread from Krakatoa, first westwards along the equator, some 2,000 miles per day, and then towards the temperate zones, the following are the main facts:

**Observation reported to writer by L. Richardson, Newcastle on Tyne.*

Krakatoa, after 200 years quiescence, suddenly burst into eruption, May 20, 1883; the explosions were heard over 160 miles away, and the ashes ascended four miles.

A period of awful eruptions began on August 26tn, lasting some 36 hours. Half the island disappeared, leaving an enormous gulf, two chief masses forming fresh islands five and seven miles off; the whole region shrouded in pitchy darkness, raining ashes and pumice, lit up by volcanic and electric glare. Batavia, distant 93 English miles, was in darkness 36 hours, the air-wave putting out all gases at 1 A. M. The height to which matter was ejected can only be estimated.* The *sound* was heard at Seychelles and Mauritius, distant 3,000 miles; sea-waves were registered the world over; air-waves circled three to five times round.†

Sound and height of projection both varying as squares, we may consider that, as the sound in August reached nearly twenty times further than in May, the height of *eighty* miles is, *a priori*, probable. For the finest dust this might well reach *one hundred* miles:

1. From the constant uprush of erupted matter.

2. From much reduced air-resistance above four miles.

3. From the uprush of the Trades (resulting in the surface equatorial calms).

4. From the consequent immense expansion of the gases; which must also increase the velocity of their outward flow.

Assuming as probable this altitude of 100 miles, the "lagging behind" of the Earth's surface in comparison, as the writer noticed on January 14, 1884, would amount to 630 miles per day. Add to this the Equatorial component of the ascended Trades, accelerated as explained above,‡ and the immense daily velocity is well accounted for, even disregarding the probable effect of electric repulsion.§

The meridianal component of the Trades, (*i. e.* the portion of their velocity measured at right angles to the Equator,) the south being in excess of the north, explains why higher northern latitudes were attained at each revolution of the dust cloud than southern.

Hardly sufficient attention has been paid to the extreme comparative prolongation of twilight in Equatorial regions compared with temperate. This also supports the view that the initial height was enormous, the downward flow of the upper currents doubtless reducing it in Temperate Zones. Perhaps, accepting the above explanation of the afterglow, it would not much exceed 25 miles, reckoning by the maximum glow; for the brightest occurred when the sun was only 9° or 10° below the York horizon. The final glare lasted, December 1, 1883, until it was 16° below.

The European records, and perhaps, also, those of the Northern United States, indicate plainly that the glows struck the continent from the S. W. Mr. Ringwood suggests that this was due to the Aleutian eruption.‖ Such a coincidence seems so unlikely that it is more natural to consider that the return S. W. Trades gave their direction to the dust-flow in these higher latitudes.

The preceding pages, after giving the result of personal observations, attempt to elucidate some less prominent features. The connection of the glows with Krakatoa and with ordinary sunsets is treated as hardly requiring further confirmation.

---

* *Dust, one inch deep, fell on a ship 970 miles E. ½ S. of Java Head* (*Nature*, 1883, *Dec. 13th.*)

† *See Nature, July 17th, and Science, Aug.* 15, 1884.

‡ *See, also, Mr. Ringwood's paper, giving observed velocities, Nature XXX.* p. 301.

§ *Nature, XXIX*, p. 180.

‖ *Nature, XXX*, p. 301.

The great secret of the whole phenomenon lies in the elevated haze-layer; diffraction by this produces "Bishop's Ring" and the first glow; further reflection, the Fore and Afterglow and Counterglow; and additional refraction, the Counterbow. Incidentally, the cloud re-illuminations, preceding the Glow and Afterglow, are likewise explained. Thus the diverse problems require but a single clue, presenting us with a unity which gives the arguments an additional and peculiar cogency to those who have felt bewildered by the vastness, the novelty and variety of the magnificent spectacles displayed upon the heavens during recent years.

APPENDIX.

Date.	Foreglow Begins.	Foreglow Finest.	Foreglow Ends.	Glow Begins.	Glow Finest.	Glow Ends.	Counterglow Begins.	Counterglow Finest.	Counterglow Ends.	Day Effects.	Counterglow Begins.	Counterglow Finest.	Counterglow Ends.	Glow Begins.	Glow Finest.	Glow Ends.	Afterglow Begins.	Afterglow Finest.	Afterglow Ends.	Days in the Period.
1885—York, Nov. 15–19	(107	72	65)	49	35	23	27	(22)	10	Constantly.				29	33	42		(38)		4
Nov. 28, Dec. 17.	(104)	80		48	44	30				Constantly.	11	22	24	24	38	50	60	71	98	10
At Street—1885, Dec. 23, to 1886, Jan. 11.		50			27					Constantly.				23	33	46	57	69	99	8
York—Feb. 4th										Hardly					31					1
Feb. 14th										any				18	28	40				1
March 3–6										Symptoms.		13		18	21	27				2
																				26

Of these 32 Glows (morning and evening) 9 were "faint," 12 "fair," 11 "fine"; 10 morning, 22 evening glows.

Nov. 18th.—The glow was very markedly *rayed*; slightly Feb. 2d.

Dec. 13th.—Finest since Spring of 1884.

A decided increase in *afterglows*; that of Jan. 11th very fine.

There was, in the afterglows, a decided increase of *purple* tint, compared with the rose of the glows.

The *morning effects* very meagre.

During the bright, cold days in March there was hardly a sign of glow of any kind.

THE "RED LIGHT."

BY HENRY C. MAINE, ROCHESTER, N. Y.

THE appearance of what are known as the Red Sunsets or Red Light, in the autumn of 1883, is regarded as one of the most remarkable meteorological events of modern times. The strange feature of the Red Light was its long duration after sunset, and a peculiar halo or corona about the sun by day. The light after sunset was usually of an orange red or a rose color, and reached far up toward the zenith in the form of an arch, with a bright spot at the highest point. There was also a bright spot and colored arch in the East, opposite the sunset point, as if produced by reflection. The horizon to the North and South was also lighted with red until a late hour, sometimes 9 o'clock. On a few occasions the light assumed the form of alternate sectors of rose colored light and blue sky, with auroral action in the colored streamers. One of the most interesting exhibitions of the kind was upon the 19th of September, 1885. At nearly every exhibition, when the rose color was prominent, auroral action could be detected. The phenomena of the sunsets changed rapidly, arch succeeding arch with changing colors as the sun went lower and lower. The halo by day had an ashen or salmon tint on the outer border, which shaded into the sky. The border was irregular, being extended in various directions at different times. (See photograph No. 2.)

The ordinary ring or halo about the sun has edges well defined, with more or less display of prismatic colors. (See photograph No. 3.)

The first step in determining the cause of the halo and unusual prolongation of sunset effects was to ascertain if they corresponded in time and intensity with other phenomena, and then determine the probability of physical connection. When the Red Light appeared, the sun was near its maximum of activity or spottedness, and the earth had been vexed with the most violent storms, and floods had been very destructive. Having observed the sun daily, since the solar activity began to increase after the minimum of 1878–9, with the result of noting a correspondence in time of the most terrific storms on the earth with similar disturbances on the sun, observation was extended to the Red Light. A brief record of the most prominent sunset displays must suffice:

There was great solar disturbance at the time the green suns and red sunsets appeared in the equatorial belt, in the beginning of September, 1883. The green suns were seen at Panama on September 2 and at Trinidad on the same date. On the first of September twenty new solar spots appeared, and on that date there were seven groups and ninety-five spots, one of which was visible to the naked eye. There were cyclones of great energy in the equatorial seas at the time, and the captain of a dismasted vessel was one of

NO. 1.—THE ROSE COLORED ARCH AT SUNSET.

The rosy sunset of November 22, 1885, photographed by Henry C. Maine, showing the rosy arch and the brilliant light below it near the sun.

NO. 2.—THE SOLAR CORONA.

The Red Light corona or halo about the sun, photographed by Henry C. Maine, at noon, November 22, 1885. The vapors near the horizon are also lighted and of considerable actinic energy. The salmon color is in the faint outer haze surrounding the central brightness.

the first observers of the strange light in the sky. The Red Light appeared in Western New York on November 24, 1883, after a severe storm had passed over the great lakes. There was great solar disturbance at the time and the light was at a maximum on the 27th. On that day, the ashen halo mentioned above was very conspicuous. This persisted with slight changes for more than a year. On the second of December the Red Light was not seen in Rochester, and the sun was nearly clear of spots. A number of new spots appeared on the 6th, and on the 8th the Red Light re-appeared. It brightened until the 10th, when it was very brilliant. The Red Light faded as the sun storms disappeared by the sun's rotation. December 21st a spot area of large extent appeared, followed by great meteorological disturbance, and the Red Light shone again, reaching great brilliancy on the 26th of December. This maximum was also noted by Dr. F. A. Forel, at Morges, Switzerland. The light waned until January 1st, when there was an ordinary sunset. On January 2nd active sun storms appeared and on the 3d, after an electric storm which drove telephone operators from their instruments in some places, the Red Light re-appeared. After a great storm, the light was brilliant January 9th and morning of the 10th. On the 17th the light was brilliant, following new solar storms. On January 25th the light was very bright, following a great chain of sun storms. Hurricanes occurred in England on the 22nd and in France and England on the 26th. The Red Light then decreased in brightness. On the 11th of February active sun storms re-appeared; tornadoes occurred in the South on the 13th and the Red Light was noted on the 14th. On the 19th two new sun storms came, the Red Light increased, and six southern states were swept by tornadoes. The sky was of a lurid red at midnight, probably from electric action upon vapors of the atmosphere. A new sun storm came February 24th, and the light continued brilliant, but faded in a few days. [The greatest brilliancy of Red Light, and severest terrestrial storms were noted when sun spots were between the eastern limb and the sun's meridian.]

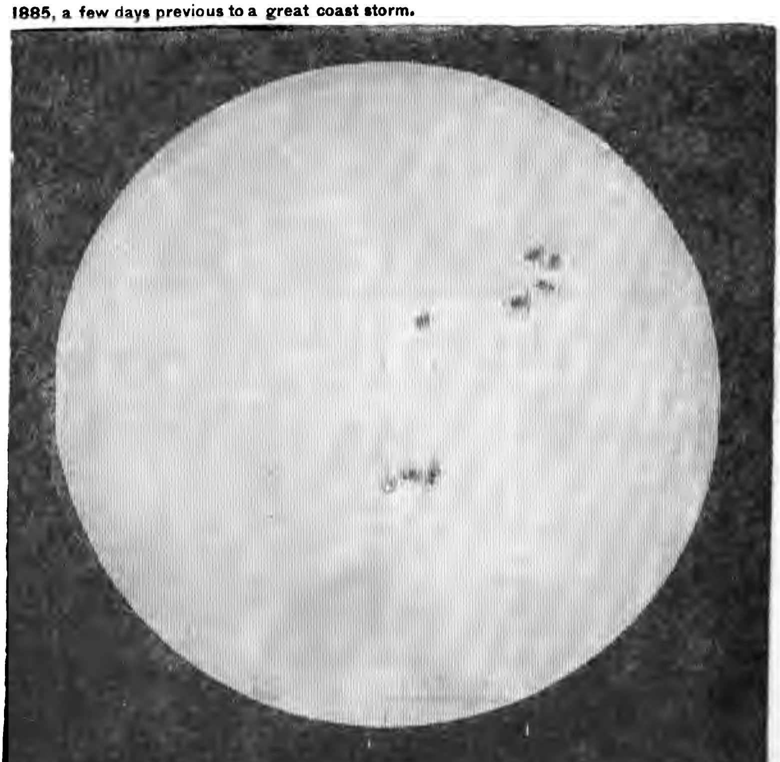
On March 2nd, 5th and 6th, new sun storms appeared and the light shone brightly. A destructive general storm followed. More sun storms came on the 13th and 14th and the Red Light was at a maximum on the 17th. Then there was a descent toward a minimum. March 25th, a sun storm developed on the sun's disc; tornadoes swept seven states. The sun storm developed the largest group of spots seen up to that date. The Red Light shone with remarkable brilliancy on March 27th. April 1st a great chain of sun spots appeared; tornadoes followed in five states and on the 5th the Red Light was intense.

Thus the light fluctuated through the entire spring and summer of 1884. In the autumn of that year the skies were very brilliant at intervals, always corresponding with the intensity of solar action. In the late winter and spring of 1885, the sun storms began to diminish, the Red Light nearly disappeared and the peculiar halo about the sun was no longer conspicuous. Toward the middle of May there was a marked renewal of the solar storms and by the 1st of June the spots were very numerous and large. During June the sun was the seat of convulsions of the most remarkable character, (see photographs of June 20th and other dates,) accompanied by a long series of very destructive storms in all parts of the world. Early in July the Red Light re-appeared. On the 5th it was seen in Rochester, and in Oregon* two days earlier. On the 31st of July the brilliancy of the Red Light reached a climax. The bright rose colored spot above the sunset point again lighted objects like a second sunset, and appeared self-luminous.

*The Western sky was colored a bright roseate hue last evening and all around the horizon and up to the zenith the clouds were fringed with red, a repetition of the red sunsets of last summer. This is the first time the phenomenon has been seen in any degree of magnitude this season.—*Portland Morning Oregonian, July 4, 1885.*

NO. 3.—PRISMATIC CIRCLE OR HALO.

Halo of water vapor at a low altitude, photographed by Henry C. Maine, on Nov. 20th, 1885, a few days previous to a great coast storm.



NO. 4.—GREAT GROUP OF SUN SPOTS.

The sun, June 18th 1885, photographed by Henry C. Maine.

The sunsets at this date were, as I observed, mostly of a rose color, which varied in intensity. They continued with varying brilliancy through August. The halo about the sun had re-appeared as a white corona, which increased in density until the salmon color on the outer border was noted again on the 2nd of September as very conspicuous, as was also the Red Light. The halo still persists and was quite brilliant on the day of the annexed photograph, November 22, 1885. By reference to the records of the Signal Service, it is noted that the Red Light varied in intensity at different places on the same date, showing conclusively that local conditions must have had a part in producing the phenomena. The best observers reporting to the Signal Service noted the difference between the orange* and rosy sunsets. The Red Light continued during September with the usual fluctuations†, being very brilliant on the 14th, and some days thereafter, following a great solar disturbance preceding the Washington Court House tornado.

These observations show that these phenomena, great storms on the sun, extended and severe meteorological disturbance on the earth, and the red sunsets, corresponded in time and intensity. The fluctuations of the Red Light also corresponded with the periods of change in solar agitation††. Is there a fair presumption of a physical connection?

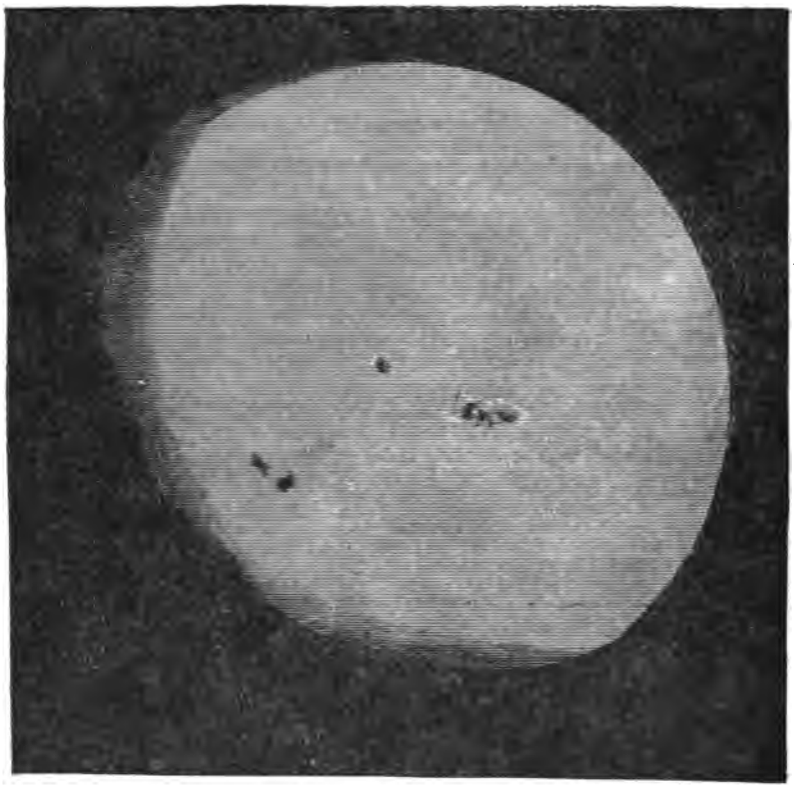
The persistence of the peculiar halo about the sun for more than a year, while the red sunsets were very unequal, sometimes disappearing altogether, indicates that there must be several factors to produce the sunset phenomena. Some of these factors were less changeable than the others. The halo showed but little change for a long period, although it was noted that on most occasions the Red Light was brilliant at night, when the halo was most conspicuous. What was the condition of things which rendered the halo persistent while the sunsets changed, almost wholly disappearing at intervals?

A terrific volcanic eruption in the straits of Sunda, Island of Java, on the 26th of August, 1883, has been regarded by many as the cause of the red sunsets. It has been held that the dust from the crater spread over the whole atmosphere of the globe at a great height, reflecting back the sunlight, after the sun had set, for a greater length of time than was usual. If the medium of reflection were dust suspended permanently in the atmosphere; and if the dust caused the solar halo, the presence of the halo about the sun by day ought to prove the presence of the dust, and the red sunsets, which are supposed to have been dependent on that dust, should therefore have been uniform during the time the halo was visible. But the sunsets were not uniform during that period, as has already been shown. This does not, however, wholly exclude the dust as a possible factor. But it is difficult to conceive how dust could remain in suspension at so great a height for more than a year, then disappearing for a time and returning again last July and August. To explain the long suspension of the dust, those who adhere to the "dust theory" have assumed that it may be mingled with water vapor at a great height. Judging from observation, and the remarkable localization of the red sunsets on many occasions, as before noted, water vapor must be considered a very important factor in their display. The

*Vevay, Indiana: Yellow or orange sunsets were observed on the 1st, 5th, 13th, 15th, 17th, 20th, 28th and 30th. Rosy sunsets were observed on the 3d, 8th, 9th, 10th and 16th.—*Signal Service Monthly Weather Review for August, 1885.*

†The color of the skies after sunset again deserves note. Many observers record especial coloring, on dates from the 12th to the end of the month. The colors are variously described as orange, crimson and pink.——*Bulletin of New England Meteorological Society for September, 1885.*

††M. Faye says: "It is what may easily happen in the progress of a periodic phenomenon which passes rapidly, and without fluctuation, from a minimum to the following maximum, but which passes slowly, by a series of secondary oscillations, from the maximum to the following minimum. This is in effect, the well-known progress of solar spots."



NO. 5.—ACTINIC ENERGY ABOUT A SOLAR STORM.

The sun, June 20th, 1885, at noon, photographed by Henry C. Maine. The great group of spots was about 110,000 miles long. The actinic energy in the region about the sun storm was so intense that other parts of the sun are left in shadow. Upon the 20th destructive storms swept the Northern States.

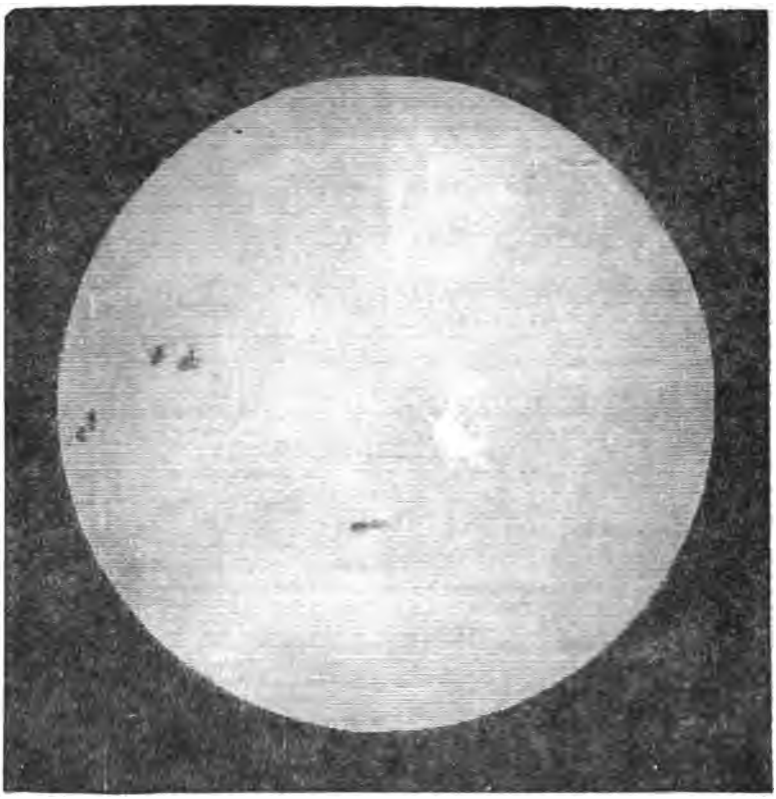
maintenance of water vapor at a height sufficient to reflect or refract the light of the sun after it is twenty degrees below the horizon, a distance which has been calculated by Mr. Serviss and others, requires unusual conditions. Where shall the conditions be sought? Do they exist in the earth itself or its atmosphere? Evidently they do not. Then they must be sought outside, and can be found nowhere except in the sun. The sun's intense activity during the past five years supplies all of the conditions necessary to raise the vapor, by added heat and electrical action, to an abnormal height. But the same condition of the sun which would elevate the vapor to a great height, would also greatly increase evaporation from the waters of the globe, and give rise to excessive rainfall. As a matter of fact, such rainfalls have occurred and are now occurring.

Proceeding a little farther, it will appear that a condition of the sun which would produce the effects noted, must also have some appreciable effect upon the sun itself and its immediate surroundings or vaporous envelope. In an annexed photograph (No. 6) of the sun, June 12th, 1885, will be seen a luminous cloud of enormous dimensions, apparently floating high above the sun's surface, for it is brighter than the sun itself. This matter, (probably blazing hydrogen,) if it does not pass out among the worlds of the solar system, goes to increase the nebulous matter about the sun. During the extended maximum of solar activity, (which has been stretched out two or three years beyond the ordinary limit,) this matter has passed out almost continually into the vapor envelope of the sun, as smoke and vapor rise in our atmosphere. But this sun vapor rises with much greater velocity from the sun, as the attraction of the sun is greater than that of the earth. The great increase of the eruptions of sun vapor during the present sun-spot maximum, would enormously extend the vapor shell about the sun. If the earth is involved in an envelope of its own dust thrown to an unusual height by the Java volcano, as the "dust theorists" claim, how much more must we expect the sun to be involved in its own vapors, since the activity there exceeds by a million or more times the feeble efforts of a world cooled sufficiently to be inhabitable. The sun has the reputation of being a nebulous star. Tennyson says in "The Princess":

> "There sinks the nebulous star we call the sun,
> If that hypothesis of theirs be sound."

Nearly every astronomer who has observed the sun has observed the passage of vast, luminous vapor clouds, mostly hydrogen, into the sun's atmosphere, or away from the globe of the sun. Professor Young saw such an event in 1871 and recorded it. The cloud rose to the height of two hundred thousand miles from the edge of the sun, at the rate of 167 miles a second, before it faded from view in the spectroscope. Professor Young calculated that the first outburst of this vapor must have been at the rate of at least 300 miles each second. Louis Trouvelot, at Meudon, near Paris, saw a mass of luminous cloud move out from the sun on the 16th of August, 1885. The observers at New Zealand of the total eclipse of the sun, September 9th, 1885, saw with the naked eye a red flame shoot out near a rift of the corona. So far as known, no such vapor cloud was ever photographed until last June, except during a total eclipse. Professor Young said in his address before the American Association for the Advancement of Science, at Philadelphia, in 1884: "As regards the actual existence of an extensive gaseous envelope around the sun, it may be added that other appearances than those seen at an eclipse seem to demonstrate it beyond question—phenomena such as the original formation of clouds of incandescent hydrogen at high elevations and the forms and motions of the loftiest prominences."

Besides the reasons already stated for believing the sun's vaporous envelope is enormously extended during great solar activity, there is another which is most persuasive, and which explains a puzzling matter in a reasona-



NO. 6.—HYDROGEN CLOUD.

The sun, June 12th, at noon, 1885, photographed by Henry C. Maine, showing luminous cloud of hydrogen.

ble way. That matter is the peculiar retardation of Encke's comet during certain of its perihelion passages, and absence of retardation at other passages. Professor Simon Newcomb says in his Popular Astronomy: "Dr. Von Asten found that between 1861 and 1865 there must have been a retarding action like that supposed by Encke. Carrying his work forward to 1875, he found that between 1871 and 1875 there was once more evidence of a retardation, about two-thirds as great as that found by Encke. The absence of such an action between 1865 and 1871, therefore, seems quite exceptional and difficult of explanation."

It will be seen by reference to the past records of solar activity that the years of retardation were years during or immediately following maximum solar disturbance. The comet was probably retarded then because the solar envelope was greatly extended; and the comet had to move through the vapors thus sent out into space by the eruptions below. When the solar activity in a measure subsided, toward the minimum period, the vapor thus thrown out condensed and returned to the sun or was dissipated in space. So the comet would meet with less resistance upon another return. It was the opinion of Sir William Siemens that the matter thrown out from the sun's equatorial regions passed out beyond the earth's orbit and returned again by re-curving to the sun's poles. If this theory is true, more matter would pass out from the sun during maximum solar activity than at other times.

Bearing all these facts and theories in mind, is it not probable that the violent solar eruptions during the past five years have so loaded and extended the solar envelope that the nebulosity has become visible, and that the visibility began in the autumn of 1883? The effects of the solar eruptions upon our atmosphere might have been such as to aid in rendering the sun's envelope visible through vapor at an abnormal height. Such conditions explain the persistence of the solar halo, and its changes in form, while the sunset phenomena which depended partly upon local atmospheric conditions, varied from day to day. The halo or corona about the sun itself may have been exaggerated to our view, greatly beyond the actual limits of the solar envelope, by the condition of our atmosphere. Indeed, part of the display must be atmospheric. Suppose an extension sufficient to retard Encke's comet, which had a perihelion distance of about 30,000,000 miles, and it will not be far from the corona, which persisted from November 24th, 1883, for more than a year, and is still seen at intervals after great solar activity, and meteorological disturbance on the earth. But the corona of the present maximum period must be much greater than the coronas which were encountered by the comet on the dates mentioned by Dr. Von Asten.

Given this corona or envelope with sufficient density toward its outer edge to reflect the sunlight, and we have the rose colored arch, with its bright spot, which followed the sinking of the sun, with the brilliant reflection in the East; also the sunrise effects which were quite as notable. Given this corona, and the character of the sunset would change from day to day through the changing condition of the vapor and possibly volcanic dust in our atmosphere. When the atmosphere was heavily laden with vapor and possibly dust from Krakatoa, the arch would be lost in the orange red glow of the gorgeous sunsets, as on November 27th, 1883, and later dates. When the dust had settled, if it was ever in our atmosphere, at the latitude of New York, the rosy arch would persist as it did and the corona would also remain by day. The arch lighted the dust and watery vapor and the image of the arch was projected on our atmosphere; but when both dust and vapor were at a minimum, the arch alone was seen, with a faint rose color. This color is the one that might be expected from the character of the vapor, mostly hydrogen, in the sun's envelope or corona.

Prof. C. A. Young says in his work on the sun, page 207: "The observations of the eclipse of 1871 by Lockyer and others show that hydrogen in a

feebly luminous condition is found all around the sun, and at a very great altitude—far above the ordinary range of prominences." This observation was near the sun spot maximum, and this accounts for the success of the observation, when luminous hydrogen was not observed at other eclipses.

The slightly varying brilliancy of the rosy arch, and of the halo by day is accounted for by the varying energy of the solar eruptions, the condition of the sun changing the condition of the envelope about it, and also affecting the earth's atmosphere. The auroral action of the Red Light is also dependent upon the solar condition.

With the corona receiving and reflecting the sunlight after the sun had set, it is not necessary to conceive that the water vapor was raised to so great a height as to reflect the sunlight after the sun was twenty degrees below the horizon. But the vapor must have been elevated considerably, as the condition of the sun and the excessive evaporation would warrant this. But such elevation to fit any theory must depend upon the sun and its increased activity. The duration of the Red Light after sundown was varied by the varying height and density of the water vapor or dust, which were dependent upon meteorological conditions.

Prof Balfour Stewart, the eminent director of the Kew Observatory, says that "the magnetical and meteorological processes of the earth are most pronounced when there are most sun spots." The intensifying of terrestrial meteorology has been so pronounced during the past five years that no argument is necessary here. The record of the tornadoes, cyclones and floods is a part of the history of those years, and is spread out everywhere in the daily press.

From all these considerations it would seem that there is a reasonable presumption of a physical connection between the unusual solar activity and the Red Light, and that the one is the principal cause of the other.

ADDENDUM.

January 4, 1886.

DR. SWIFT:

Dear Sir: My attention has just been called to the following from the *Scientific American* of the 2d of January, 1886. I presume it had not before been published in this country; and appearing a month subsequently to the date of my essay in which the same views of the corona were independently advanced, it should not interfere with my claim to original treatment. I trust that you will submit this note with accompanying extract as an addendum to the essay of "OBSERVER."

THE CORONA VISIBLE TO THE NAKED EYE ON HIGH MOUNTAINS.

Scientific American, Jan. 2, 1886.

Professor Tacchini, a great authority among scientists, gives a remarkable piece of information in a letter to *L'Astronomie*. He records that M. Favel asserts that on high mountains, when the sky is serene, the solar corona is so apparent that it strikes all observers. The mountaineers and dwellers among the Alps agree in affirming that the phenomena is something entirely new. Tacchini also gives an experience of his own on the subject. He made the ascent of Mt. Etna in July last. When near the volcano, at a height of over 10,000 feet, under a clear sky of a dark blue tint, he saw the sun surrounded by a white aureola, concentric with a magnificent corona of a coppery red. The corona was transformed near the horizon into an arc less defined and of much greater extent.

THE ORIGIN OF THE RED GLOWS.

BY REV. SERENO E. BISHOP, HONOLULU, HAWAIIAN ISLANDS.

THESE brilliant phenomena first began to be observed on the 28th day of August, 1883. They have continued with varying but diminishing intensity for more than two years. They first appeared in great splendor along an Equatorial belt of 18,000 miles or more. They gradually extended with reduced brilliancy to the Temperate zones, exciting the wonder of Europe and the United States in November, 1883.

The most conspicuous of these phenomena take place during one hour or more before sunrise and after sunset. They may be considered as a great intensifying and prolongation of common twilight sky reflections, in consequence of a recent introduction into the higher regions of the atmosphere of some kind of finely divided matter which powerfully reflects the sun's rays, especially the red. The usual order of changes is as follows.

Clouds not obscuring the view, the horizon where the sun has just set is occupied by a bright silvery luster. Above this to a height of 30° or 40° a yellowish haze fills the Western sky. Although seemingly opaque and dense, the presence in it of Venus or the crescent moon show it to be entirely transparent. This haze rapidly changes in color and extent, ranging through greenish yellow and olive to orange and deep scarlet. As the dusk advances, orange and olive tints flush out on all sides of the sky, especially in the East. The chief body of color gathers and deepens over the sunset, rapidly developing the red. In from 20 to 30 minutes after sunset, deep scarlet has overpowered all other hues, flaming along 60° of horizon, and 10° of altitude. This rapidly sinks and intensifies. There is a dark interval above the red. The stars begin to appear. While yet the color flames low, above the dark space appears a repetition of the orange and olive hues. Seen against the night-sky, these secondary reflections or after-glows are seemingly more brilliant than the primary ones. Again the colors change and deepen into red, and after the stars are all out, and the earlier flame has sunk below the horizon, and far later than any common twilight, a vast blood-red sheet covers the West. It has been seen rising as high as 20°. As it sinks and rests low on the horizon, in the dark night sky, it precisely simulates the appearance of a remote and immense conflagration, for which it has in many places been mistaken. I have known our usual 30 minutes of twilight to be prolonged to 90, before the last glow disappeared.

In the dawn recur the same appearances, but in inverse order. In September, 1883, they were singularly impressive and even terrific, as the first low sullen incandescence rose and spread and glared among the stars, as if the very heavens were in conflagration. Then, as well as at nightfall, a marked division occurs between the night-glow and that nearest to the sun. During the earlier weeks of the display, the dark interval was often extremely distinct. One observer [a] described it as a "black bow." Another saw the shadow of the remote horizon sharply projected upon the under surface of the haze-canopy, but with fine serrations, probably the shadows of platoons of cumuli [b]. Evidently at that early date the canopy of floating haze had a well-defined under-surface.

From the beginning, the upper limit of the night-glow has always been indefinite, since its light was reflected to it from the broad surface of the first Glow, while the latter showed a clean shadow of the horizon from the sun itself. In general it may be said that the tropical displays of these Glows at their birth during the first week in September, as far surpassed the mild Glows seen world-wide in November, as the plunging surges of a tempest surpass the tripping crests of a breeze. The entire dome of sky above and around seemed to heave with billows of lurid light, as the portentous masses of color poured out of the pellucid blue, while the West outflamed in broad conflagrations.

In September, during the day, as well as after sunset, many portions of the haze-canopy were noticeable as having a wavy or rippled structure. [c] A conspicuous object when the sun is high has been from the first the opalescent silvery glow around the sun. This occupies a circle of 25° radius or more. The outer part develops a pinkish hue, which against the blue sky shows lilac or chocolate tints. These have a singular effect when seen through rifts of cloud, as Capt. Penhallow [d] saw them on September 18th, 1,000 miles N, E. of Honolulu. This sun-glow has been particularly discussed by M. A. Cornu in the *Comptes Rendus*, of September 23. 1884. He remarks peculiar modifications therein of the atmospheric polarization of the sun's rays. Prof. F. A. Forel has repeatedly discussed this sun-glow, which he has named [e] the "Cercle de Bishop," after the first observer of the phenomenon at Honolulu. Prof. Huggins found this sun-glow putting an end to his previously successful photography of the Solar Corona.

The height of the main body of this haze in the atmosphere has been variously estimated at from 15 to 40 miles. The present writer, as the result of much and early observation, has no doubt that in the early part of September, 1883, no part of its under surface was less than 30 or 40 miles above the ground. All estimates should be based upon the first reflections and not upon the secondary glows. No decisive tests of the nature of this reflecting matter have been secured. The spectroscope has distinctly indicated the presence of large quantities of aqueous vapor, [f] accompanied by other peculiar influences. Fresh fallen rain and snow have repeatedly yielded a dust of microscopic particles possessing the same constitution as the fine ash-fall from Krakatoa.

The most generally accepted theory of the source of this new matter in the sky, attributes it to the great eruption of the crater of Krakatoa or Krakatao in the Straits of Sunda on the 27th of August, 1883, one day before the first definite record of Red Glows, which were seen on the 28th, at both Mauritius and the Seychelles, 3,500 miles west of Krakatoa. Before considering the evidences in suport of this theory, notice needs to be taken of two other hypotheses, which have been advocated.

One of these assumes the meeting of our globe with some cosmic cloud of impalpable dust, which was arrested in the upper strata of the atmosphere.

a. Nature, vol. 29, p. 549. *b. Nature, 29, 549.* *c. Nature, 29, 174.* *d. Nature, 29, 174.* *e. Archives des Sciences physiques et Naturelles, tome 13, p. 465.* *f. C. Michie Smith, Nature 29, 28.*

The other hypothesis supposes the cosmic cloud to have been composed of hydrogen, which united with the oxygen of the atmosphere to form the aqueous vapor evidently constituting so considerable a part of this haze.

The latter hypothesis seems open to the objection that such uniting of the two gases is usually attended with active combustion, none of which was observed.

Both hypotheses suffer from the total absence of evidence that any such cosmic cloud did approach the earth on or before August 28th, or since that time. The matter actually introduced into our atmosphere is brilliantly conspicuous in the sunlight. Yet we are asked to believe that a vast nebula of such matter approached unseen and enveloped the earth. In 1861, the tail of an immense and brilliant comet actually swept the earth. Yet so tenuous was the impinging matter that no traces of its presence were left behind. A cloud sufficiently dense to create the present haze, must in its approach have presented the aspect of a most compact and refulgent body. So far from being possibly unobserved, it must have terrified mankind.

Another and most serious objection lies in the original narrow localization of this haze in an equatorial belt. It is difficult to conceive of a cosmic cloud possessing a mass adequate to the immense effects produced, which should not occupy such dimensions as to completely envelop the globe at once, producing Glows simultaneously all over the earth, not to consider the improbability that the course of such a dense little nebula after collision should precisely coincide with the Equator. It must be remembered that stray cometary or nebulous matter (not solid meteors) afloat in cosmic space, since it possesses small mass and feeble centripetal force, necessarily assumes immense volume and extreme attenuation, compared with which this haze is solidity itself. The entire quantity of this peculiar matter actually diffused in our atmosphere, must originally have been equivalent to many cubic miles of solid matter, which represents a volume of cometary material immensely exceeding the dimensions of the largest planet. The actual localization of the first Glows in the Tropics thus precludes reference to cosmic sources, and compels us to seek a terrestrial one.

Many have felt that the long protracted continuance of this haze in the air necessitates the supposition of renewed supplies from fresh sources, as if perhaps the earth were continuing to traverse successive regions of cosmic vapors, (which no one has seen). Had there been but one original introduction of the haze, must it not long since have been precipitated and disappeared? But we have to consider how slow is the subsidence of even coarse common dust, especially in currents of air. The haze matter in question had probably 40 miles to fall. If only 20 miles or 105,600 feet, it must fall 144 feet in a day to reach the ground in two years. It seems improbable that these ultra-microscopic particles could descend at one-tenth of such a velocity? [g] It seems likely, on the contrary, that the finer particles of this matter will continue suspended and produce their Glows for many years to come.

Leaving these nebulous imaginings, let us pursue the plain, if humble, historical method of inquiry. When and where were these phenomena first observed? Under what peculiar conditions and with what attendant circumstances did they appear? In what successions of time and place did they first occur, and to what actual point of origin on the earth's surface may they be traced?

Pursuing this indispensable method of physical investigation, we find that the earlier appearances of the sunset Glows, were as a rule immediately preceded by a peculiar veiling and discoloration of the sun's disc, commonly termed the "Green Sun." While the sky was cloudless, or faintly obscured by undefinable haze, the disc of the sun was described [h] as pallid, livid, bluish,

g. John Le Conte, Nature, 29, 404. *h. Nature,* 28, *pp.* 576, 577—*Vol.* 29, *pp.* 28, 76, 133, 181, 549.

coppery, greenish, "bird's-egg hue," "plague-stricken." It could be directly viewed with the naked eye, and its spots distinguished. At the altitude of 40° the sun generally resumed its ordinary aspect, but again turned pallid and green as it descended in the West. In some cases the sunset glares immediately succeeded, while in others they were not reported, the haze probably having been too dense for the sun's rays to penetrate it obliquely, so as to be reflected from its under surface. The first appearances of the Red Glows were so intimately associated with the Green Suns that it is impossible not to treat them as different aspects of one and the same phenomenon.

It seems in place here to cite Mr. Whymper's observation [i] of Green Sun and wonderful Sky-Glows combined. On the third of July, 1880, on the upper slopes of Chimborazo, Mr. Whymper witnessed an eruption of Cotapaxi, smoke from which drifted over the observer's position. Seen through it, the sun's disc assumed a peculiar green, while the changing colors of the sky "surpassed in vivid intensity the wildest effects of the most gorgeous sunsets."

From such records as were accessible, I have constructed the accompanying tabulated statement of the earlier recorded appearances of the Green Suns and the Red Glows. The latitude and longitude of each locality are given in the table, with the date of the first appearance of the phenomenon at each point. The distance from Krakatoa is estimated in English miles, the number of hours in transit and the velocity of the current calculated. The source of information is specified for each of the seventeen different localities, three of which were on vessels at sea in the Pacific. To these, Maranham might be added. I lack the needed reference. At six of these localities, both the Green Sun and the Red Glows were reported as having been seen on the same day. At four points only Red Glows were reported, and at seven only Green Suns.

The most remarkable fact evidenced by this table is that the earliest appearances of these phenomena are thereby traced along a line of points, successive from East to West, lying very near the Equator, beginning at the Seychelles Islands in the Indian Ocean, and running thence in successive days through Cape Coast Castle, Trinidad, Panama, and Fanning's Island, arriving at Strong's Island on September 7th, having traversed a great circle for 17,600 miles in about 230 hours.

It thus appears that the original haze cloud, which first produced the Red Glows, swept west from the Indian Ocean in an Equatorial Stream or Belt, which traversed more than two-thirds of the circumference of the globe at an average velocity of nearly eighty miles an hour. A precise estimate of its velocity between successive points is prevented by the imperfection of the observations made. The date at Cape Coast Castle is uncertain by one day. The dates at Seychelles and Mauritius are probably vitiated by the copious diffusion of volcanic smoke prior to the regular movement of the upper stream. It seems quite clear, however, that an average velocity of about 90 miles an hour during the first half of the course of this haze-stream became reduced to about 60 miles in its later stages. These data appear to favor the conclusion of Mr. S. E. Bishop, [j] that a stream of vapors was discharged over and upon the upper surface of the atmosphere of the Indian Ocean, by a powerful *initial* impulse, which drove it straight in a great circle, independently of atmospheric currents, and that this stream gradually suffered retardation as it descended into the atmosphere, finally ceasing over the Caroline Islands.

Without necessarily accepting this writer's theory, showing how such an impulse would be generated by the rotation of the earth, it seems clear at least, that the inception of the Equatorial Haze-stream, and its attendant Glows has been traced with positive certainty as far as the western side of

---

i. *Nature*, 29, p. 199. j. *Hawaiian Monthly*, April, 1884.

LOCALITY.	LAT.	LONG.	DATE.	DISTANCE.	HOURS.	VELOCITY.	GREEN SUN.	RED GLOW.	REFERENCE.
Krakatoa.........	6° 10′ S.	105° 30′ E.	Aug. 27th, A. M.						
Mauritius.........	20° 20′ S.	57° 40′ E.	" 28th, P. M.	3,600	30	120		R. S.	*Nature*, Vol. 30, p. 279
Seychelles...	4° 30′ S.	55° 20′ E.	" 28th, P. M.	3,480	30	116	G. S.	R. S.	" " 30, 280
Cape Coast Castle	5° 25′ N.	1° 15′ W,	Sept. 1st, A. M.	7,420	90	82	G. S.		" " 29, 133
Trininad	10° 30′ N.	61° 26′ W.	" 2d, A. M.	11,600	127	91	G. S.	R. S.	" " 28, 577
Barinas, Ven.....	7° 44′ N.	70° 22′ W.	" 2d, A. M.	12,220	128	96	G. S.		" " 29, 76
Panama.....	9° — N.	79° 35′ W.	" 2d, A. M.	12,860	128	100	G. S.		" " 29, 152
C. S. Hurlburt...	17° — N.	125° — W.	" 3d, P. M.	16,000	201	80		R. S.	" " 29, 549
Fanning's Island.	2° 40′ N.	159° — W.	" 4th, P. M.	18,400	218	84	G. S.		" " 29, 549
Jennie Walker...	8° 20′ N.	155° 25′ W.	" 4th, P. M.	18,200	218	84	G. S.	R. S.	" " 29, 549
Zealandia.........	5° — N.	163° — W.	" 5th, A. M.	18,800	230	82	G. S.		" " 29, 181
Maalaea	20° 49′ N.	156° 28′ W.	" 5th, A. M.	18,300	229	80		R. S.	" " 29, 573
Honolulu.........	22° 17′ N.	157° 52′ W.	" 5th, P. M.	18,400	241	76	G. S.	R. S.	" " 29, 174
Strong's Island...	5° — N.	162° — E.	" 7th, (6) P. M.	21,100	256	83	G. S.		" " 30, 537
New Ireland.....	5° — S.	152° — E.	" 1st, P. M.	8,200	107	80		R. S.	" " 29, 259
Madras	18° 13′ N.	80° 12′ E.	" 10th, A. M.	1,900	332	6	G. S.	R. S.	" " 29, 28
Ongole............	15° 32′ N.	80° 8′ E.	" 10th, P. M.	1,900	342	6	G. S.	R. S.	" " 28, 576
Soudan...	15° — N.	32° — E.	" 24th.	5,100	672	8	G. S.		" " 29, 181

the Indian Ocean, and back to the 28th day of August. Eastward of this, our search is arrested by a vast pall of volcanic smoke proceeding from the greatest eruption described in history. But if we stretch our line back through this obstructing veil, 30 hours in time and 3,500 miles in distance, we find ourselves confronted by the great final explosions of Krakatoa on the morning of August 27th. Projected aloft from this crater by a succession of colossal explosions, a vast dome or cone of volcanic smoke on that day covered a region of not less than 400 miles in diameter with absolute darkness for many hours, and spread a deep gloom for not less than 1,000 miles in every direction. From the summit of this immense reservoir of vapors piled to an unknown height, the great Equatorial Haze-stream, appears to have issued, and sped westward around the globe. We have unquestionably traced it to its source in the vapor-mass that overhung the Indian Ocean less poetic than a cosmic nebula, but possessing reality, and with it have found the one sole and indisputable origin of the Red Glows which attended its course.

This does not imply that the swift Equatorial Smoke-stream embodied the whole of the glow-producing medium. It seems more probable that the larger portion of the vapors which became slowly and irregularly diffused over the globe during the ensuing seventy days, were drifted from the broad vapor-mass after the special stream had ceased. Thus we find the Indian peninsula untouched by the narrow stream which must have passed south of the Equator. But 14 days afterwards, the haze arrived in full force and produced the Green Suns and Red Glows throughout Ceylon and Southern India, shortly afterwards appearing in Aden and the Soudan. We also find the Glows at New Ireland, 3,200 miles due east from Krakatoa, in four days after the last explosions. In all these cases the transportation was comparatively slow, and probably due to atmospheric currents.

We need to consider the adequacy of the eruption of Krakatoa to have produced atmospheric effects of such magnitude and extent, not only "*belting* the globe with flaming skies," as in September, but by November enveloping the entire sphere in these fiery glares. Can Krakatoa be shown to have probably ejected a *quantity* of tenuous matter sufficient for this result? And can it be believed to have delivered such matter at such a *height* that in its descent it would form a haze canopy from 30 to 40 miles above the surface?

We have absolutely and precisely traced the Glows to their source, and so have the right to affirm that Krakatoa proved its colossal capacity to emit these vapors in such quantity and to such a height, by having actually done so. It is the objector's part to prove that it could not have done so, and did not. But waiving this advantage, we cite a preliminary official Report on the nature and effects of the eruption of Krakatoa, made by Mr. R. D. M. Verbeek. [k] He makes an estimate of the quantity of those solid ejecta of the crater, which were so coarse as to be speedily precipitated. This amounted to 18 cubic kilometers or 4.5 cubic miles, two-thirds of which fell as ashes and pumice within a radius of nine miles. He believes that at least an equal mass was delivered at the highest parts of the column in the form of vapors and impalpable dust. It would be easy to present considerations to show that this finer portion must have vastly exceeded the coarser. But this might be speculative. We know that four and a half cubic miles of solid matter would overlay the entire atmosphere of the globe with a solid film of one seven-hundredth of an inch in thickness. This would doubtless be equivalent to many miles in thickness of such tenuous vapor and dust as have been floating in the upper ether.

As to the height of the column of ejecta emitted from Krakatoa at its highest activity, some estimate may be formed from known facts. The

k. *Nature*, vol. 30, pp. 10-14.

heaviest throes were very precisely determined [l] to have occurred at 9:55 and 10:45 A. M. on August 27th. The latter one was immediately followed by a continuous downpour of mud and ashes upon the ship *Charles Bal*, then 30 miles distant. [m] Seventy miles away, trees were extensively shattered by the weight of wet ashes. [n] Batavia, 100 miles away, was covered three inches deep with white ashes during the hours of total darkness following the greatest eruption. It seems impossible to find room for these facts on any estimate of the height of the eruptive column, as less than one hundred miles. It is true that *light* ashes might have great lateral diffusion from a column of far less height, but mud and wet ashes must have plunged quite directly downwards, so that a lateral throw of 30 to 70 miles must involve a vertical ascent of not less than one hundred.

The height supposed would have driven the eruptive column entirely through the atmosphere and far above it, so as to deliver its contents over the surface of the atmosphere, to settle slowly down through its upper strata.

That the great column did actually thus lift and rend asunder the mighty mass of the atmosphere above the crater is made probable by the unique oscillations of the barometers. A series of atmospheric waves was sped three times around the globe at the rate of 700 miles an hour. [o] The length of each undulation was one million meters, that of the lowest audible sound waves being 24 meters. Twenty miles away from the crater the mercury rapidly oscillated between the 28th and 30th inches. It is thus evident that in the vicinity of Krakatoa the upper layers of the atmosphere were swinging up and down through a vertical distance of from ten to twenty miles every 15 minutes. What could have done this less than an explosion driving clear through its entire depth?

As general evidences of the ultra-colossal character of the Krakatoa explosion may be adduced the following: 1. The waves driven upon the coasts of Anjer and Merak, 30 miles away, were found to have exceeded 35 meters or 112 feet in height. [p] Over the entire Anjer plain, fifteen miles by five, the inundation had uprooted every tree, and coral blocks of from 20 to 50 tons in weight had been torn from the bed of the sea and borne inland two or three miles. [q]

2. The detonations of the eruption were heard throughout a circle whose radius is 1,800 geographical miles, [r] equal to one-fifteenth of the surface of the earth. Yet the heaviest could not be heard within a radius of 40 miles from the crater. The sounds must have proceeded from tremendous rendings of the air at an immense height, whence the sounds were easily spread to vast distances, while from localities beneath, the massive torrents of descending ejecta cut off the sounds like a wall.

3. Ashes fell [s] at Singapore, 335 miles; at Buncalis, 915 miles N. W.; at Keeling, 1,200 miles S. W.; on the Australian coast, 1,050 miles E. S. E.; on the Arabella, 970 miles W. N. West. The entire area of ash-fall was officially estimated as at least 750,000 kilometers, [t] or as large as the Southern States east of the Mississippi.

The history of the eruption shows that upon the collapse of the mountain, on the morning of the 27th, the eruptions became submarine; [u] the ocean waters rushed into the burning depths. Under the pressure of many miles of water the lava and the waters commingled and struggled with geyser-like discharges of augmenting violence, until finally there arose a continuous column of white-hot water and lava. Through the wide throat, apparently three miles in diameter, the vast column drove upwards, expanding and

---

l. Nature, 30, 12. *m. Nature*, 29, 140. *n. Leisure Hour, July*, 1885, *page* 487. *o. Nature*, 29, *p.* 181. *p. Nature*, 30, 14—*Leisure Hour, Sept.* 1885, *p.* 636. *q. Leisure Hour, August*, 1885, *p.* 556. *r. Nature*. 30, 10. *s. Nature*, 30, 13. *t. Nature*, 30, *p.* 13. *u. Nature*, 30, *p.* 12.